INSTRUMENTS

THE MAGAZINE OF MEASUREMENT and CONTROL

VOLUME 10

JUNE
1937

NUMBER 6

TAG's BIG CHARTS *are easier to* READ

Much is heard today about chart size, but TAG Recorder Design provides **the longest pen travel—4¾ inches**—on a full size 12-inch chart . . . the longest on the market. With characteristic thoroughness TAG provides this important detail to give you a chart with much wider graduations for each degree interval. Wherever Temperature, Pressure, Level or Flow must be recorded, TAG's BIG CHARTS give you easier reading.

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

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INSTRUMENTS The Magazine of MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

Nearly two years ago we began planning an exhaustive symposium on storage battery testing, and already have several articles lined up. This first one, by Harner and Hatfield, though dealing only with one particular class of tests, has been in demand before publication. In fact, so insistent were requests for "the copy of *Instruments* containing the article by Harner and Hatfield" that we decided to print this article by itself, without waiting for the completion of all others comprising the symposium.

The articles by Bean and by Morey on flow nozzle research represent a splendid example of thoroughness: As usual, the Bureau of Standards gives the whole world an object lesson in refinement of measurements. With such an admirable start, the ASME's program will undoubtedly attain all of its objectives, to the great benefit of flow meter users. This research program deserves the financial support of all industries using flow meters. Does *your* company chip in?

Professor Williams continues, in his serial, to deal with the relation between abrasion resistance and hardness; next month he will discuss scratch methods.

This month's instalment of the serial by Batcher concludes the subject of miscellaneous applications of cathode-ray tubes; next month he will deal with an entirely different aspect of cathode-ray oscillography; sources of errors.

THE FRONT COVER

photograph, taken in the Bell Laboratories' Collaboration Laboratory, shows the primary d-c. resistance bridge, with resistance standards in the foreground.

YOU AND WE, AGAIN

IN Dearborn last month your editor had the pleasure of finding that *Instruments* was read—at least occasionally—by many engineers in a world-famous plant. On our return we asked the Circulation Manager how many subscribers we have there. It seems that each copy mailed to Dearborn is read by thirty or more Ford engineers. Such remarkable multiple circulation would be a source of pride to most editors. It is to us; but we can't help thinking of the many minor tragedies thereby caused.

Every day, throughout the country, thousands of engineers say to themselves, "I know there's a method or a device that'll do the trick. I remember seeing it. But *where* did I see it?" And even if the reader remembers that he saw it in *Instruments*, he loses time and wastes effort getting hold of the copy which does not belong to him personally. In one actual case the copy had been taken home by a high executive, and an engineer who had to have a certain reference telephoned to this office from Ohio. The cost of the call was more than that of a subscription.

We don't care how many traditions of editorship we shatter by talking business, but it would be a disservice to you if we failed to urge you to get your own personal copy of *Instruments* every month. Then, too, many of you don't know how little subscriptions cost under the Group Plan:

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So, *before* you pass *this* copy on to the next man, speak to this next man, and to a few others, and send in your group. You will be doing a favor to yourself and to your friends.

Do you live near New York? In connection with the ASTM's fortieth annual meeting there will be held an exhibit of testing apparatus and related equipment in the Waldorf Astoria Hotel, from Monday June 28th through Friday July 2nd. As usual, the Instruments Publishing Company will have a booth. Don't hesitate to make use of it. "Meet me at the *Instruments* booth" will be said over many telephone lines as usual, and if the other fellow is late, the first one to get there can relax to his heart's content.

Do you live West of the Rockies? Your editor's first real vacation in eighteen years will be a motor trip in July and August through the great National Parks, also Boulder Dam, Los Angeles, San Francisco and . . . well, drop us a line suggesting that we include *your* plant or lab in our itinerary!

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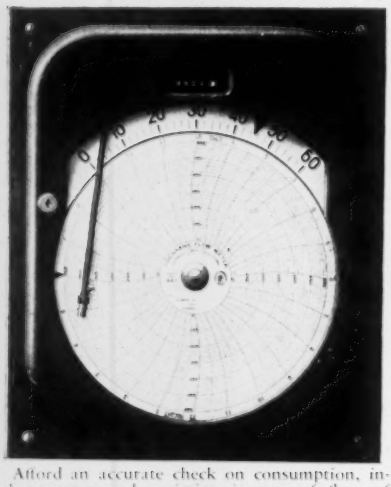
Electric and Mechanical Models



Afford an accurate check on consumption, intake, output and variation in rate of flow of steam, water, air and miscellaneous liquids and gases.

Cochrane Flow Meters are ruggedly built and extremely sensitive to variations in recording or integrating flow. Electric model operates on the super-accurate galvanometer null principle. Measurement is possible at any distance from the pipe line, facilitating grouping of instruments on central panels. Recorders of both models are *guaranteed* accurate within ½ of 1% of absolute under full load.

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NEW INSTRUMENTS

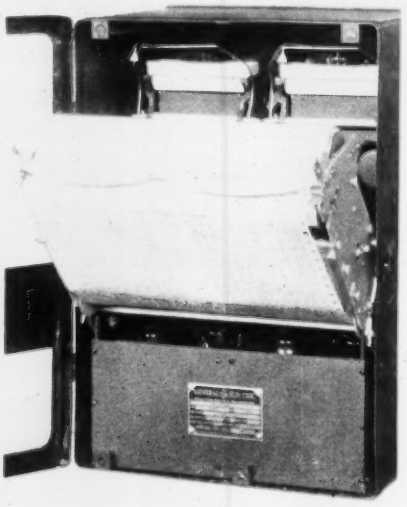
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Double Photoelectric Recorder

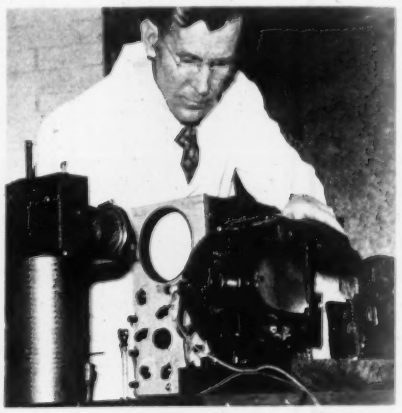
This new photoelectric instrument will record simultaneously on one chart two electrical magnitudes as low as one micro-amp. full-scale (representing power consumption of 10^{-3} watt from the measured circuit). It can be applied wherever simultaneous readings are desired. In some cases this immediately cuts testing time in half; in others it aids in discovering unusual relations between two variables. This double photoelectric recorder came into existence because of a demand for an instrument that could measure and record the surface irregularities of steel strips. This required two electric gages on both sides of the strip and directly opposite each other and two records on one chart. Two recorders were therefore combined in a single enclosing case, and a standard chart mechanism was extended to accommodate a 10" roll, with the chart mechanism either driven in the conventional way or from an external drive.



The double recorder can be applied also to record outdoor and indoor temperatures for air-conditioning work, wet- and dry-bulb temperatures, refrigeration temperatures, and other temperatures in heat-flow problems. Galvanometer-type recorders can be supplied for physiological studies. In steel mills for simultaneous recording of pressure (obtained by a strain gage on the mill housing) and thickness (obtained by the continuous strip gage) so that at a glance it is possible to see variations in thickness with changes in pressure on the mill rolls. With two continuous strip gages, one on each side of the material, a measurement of uniformity in thickness of the strip is obtained and therefore a measure of quality. Electric-gage recordings can be so related that a continuous check on operating conditions, such as poor bearings and rolls, is at hand. Other applications are the recording of high-resistance voltmeter-ammeter measurements, illumination measurements, and others requiring galvanometer types of measuring elements. *General Electric Co., Schenectady, N. Y.*

"Memory Machine"

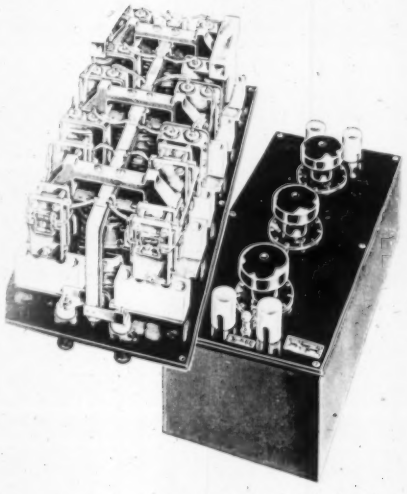
Capable of photographically recording events after they have happened, the "Memnoscope" consists of a camera focused on a cathode-ray screen, and a



system of commutating capacitors whereby the indication of the oscilloscope always corresponds to events occurring 2 cycles previously. When the relay system operates, the camera (even though slow) thus takes a picture which shows events occurring about 1½ cycles previously. Commutator has 147 bars, to each of which is connected one terminal of a 0.01 μfd aluminum foil paper wax capacitor, 1" long and ½" in diameter. Other terminal of each capacitor is connected to the shaft. Any voltage on input terminals will charge capacitors by direct conduction to a value depending on input voltage. If input voltage varies, the charge on the capacitors will also vary from capacitor to capacitor, all around the commutator. After a capacitor is charged by the input brush, it is carried around to the output brush where all or part of its charge can be recorded or used for some other purpose. The time, however, of its use is one revolution in time behind the input. One or two bars after a capacitor transfers its charge to the output circuit all of the charge remaining is in effect erased by a center brush, after which the capacitor is ready for another transfer of charge. The output wave form is the same as the input wave form and the loss in energy during transfer is negligible. *Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

al Shielded Mica Capacitor

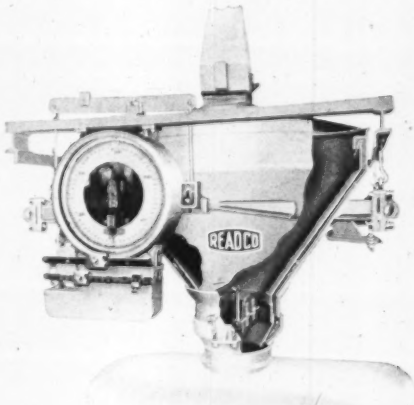
...bridges, oscillators, filters or other ...ks, this completely shielded mica ...tor makes possible quick measure... of capacitance and other precise ...mental measurements using the in... ...ence compensation method. Each of



its three dials—0.1, 0.01 and 0.001 μf—has ten steps and zero; provides a total range of 1.11 μf. Measured from binding posts, at 1000 cycles, the capacitance difference between each setting of each dial and its zero setting (other dials on zero) agrees with the nominal value of that setting to $\pm$ (0.1% + 0.5$\mu\mu$f). Phase angle of capacitance difference is <1' for the 0.1 μf and 0.01 μf dials; <2' for the 0.001 μf dial. Temperature coefficient of capacitance over normal room temperature range is <0.002% F. Minimum d-c. resistance (at maximum setting) is >2500 megohms. Capacitors may be operated continuously on 350 volts r.m.s., 60 cycles. To make each dial setting independent of the others, individual leads run from each decade to outside terminals. *Leeds & Northrup Co., 7055 Stenton Ave., Philadelphia, Pa.*

Dustless Weighing Hopper

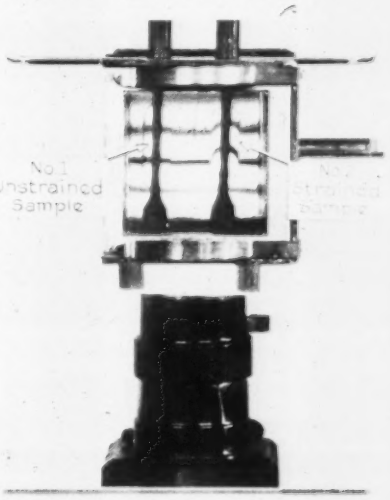
A new dustless weighing hopper, furnished with or without a weighing device, for handling powders, as in manufacturing drugs, cosmetics, paints, chem-



icals, etc., comprises a set of butterfly discharge gates for controlling discharge—these gates operating coincidentally with the sliding sleeve raised and lowered by means of toggle connections to same shaft. Sliding sleeve consists of two rings, through inner of which the hopper contents are discharged; space between rings permits displaced air (in tank or other vessel being filled) to be returned with the dust directly into two flues on interior of hopper. In practice, it has been found that the combined pressure exerted by reason of displaced air in filled vessel, plus a partial vacuum created in hopper itself by reason of discharge of its contents, automatically returns all dust to interior of hopper. *Read Machinery Co., Inc., York, Pa.*

Glass Strain Analyzer

A new strain analyzer not only makes apparent the strains in glass, quartz, etc., but is said to have the added advantage of giving directional and quantitative as well as qualitative indications. It not only utilizes the distortion of polarized light by a strained medium but makes use of the bi-refringent properties of a system of thin quartz wedges. A number of distinct interference lines are set up. These remain straight and parallel as *long as the medium between* the polarizing screen and the wedge combination *remains unstrained*. If a strained specimen of transparent or translucent material is introduced, these lines become distorted (see illustration), the degree of distortion being proportional to the strain. Direction and magnitude of stress can be determined by substituting for the specimen an unstrained rod or cylinder of the same material, loaded with selected weights. Displacement of lines in one direction indicates tension;



in the other, compression. Sensitivity is such that a light finger touch upon specimen will give a positive indication. Large specimens can be examined using containers of suitable size and moving specimen about to bring various areas within lines of observation. For inspecting small devices such as thermometers and thermostats, a small container is adequate, even for production-line testing. In the inspection of glass-to-metal seals, analyzer permits detecting leaking joints. Immersion of specimen in a liquid of equivalent refractive index is generally necessary if specimen is not flat, of uniform thickness, or does not have clear surfaces. Benzol or Russian mineral are suitable for most applications. For laboratory analysis the new analyzer permits studying optimum annealing temperatures, methods, and applications. *General Electric Co., Schenectady, N. Y.*

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Process Control for sensitive, stable automatic control of temperature, pressure, liquid level, flow and other factors as applied to industrial processes. Responds to changes quickly, without overtravel or hunting. Ask for Bulletin No. 101.

Combustion Control that is simple but *complete* for providing economical operation of boilers of 200 h. p. and larger. Details in Bulletin No. 102.

Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 11.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.

Control Drive

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

G-3

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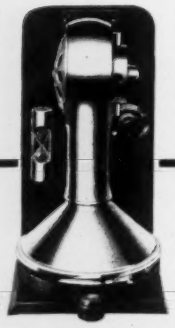

MOISTURE
Content by Drying

The Moisture Teller as illustrated above will dry 50 or 100 gram test samples at the rate of one per minute. Test samples are weighed before and after drying to obtain moisture content in percentage.

Used in the following industries: Foundry — Paper — Mining — Rubber — Milling — Textile — Tobacco — Food — Brick, etc.

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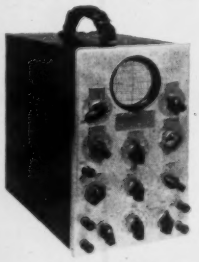

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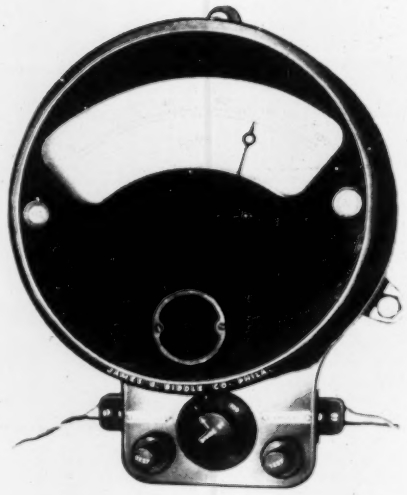
Upper Montclair New Jersey



Switchboard Models of Direct-reading Ohmmeter

These are believed to be the first switchboard-mounting models of the direct-reading ohmmeter class of electrical instruments. Case diam. is 10" and pointer-and-scale design is such that resistance values can be read from a distance. New instruments operate on same principle as maker's "Megger" portable insulation testers—true cross-coil ohmmeter—but they do not contain generators and are to be operated from a factory d-c. source or rectifier or battery. This required external voltage is 3, 100, 250, 500 or 1000 volts, depending on the ohms or megohms range desired. Numerous ranges are available, the lowest being 0 to 0.1 ohm and the highest 0 to 100 megohms. Double- and triple-range instruments are available. *James G. Biddle Co., 1211 Arch St., Philadelphia, Pa.*

Electric Speedometer

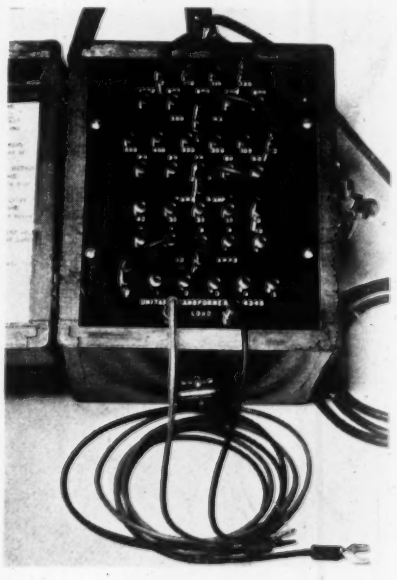
A new a-c. speedometer for steam, diesel and electric locomotives consists of three elements: (1) a generator suitable for axle mounting, connected by wires (2) an indicator for mounting in the cab, (3) a junction box with a variable resistance to compensate for wheel wear. On steam locomotives the generator is securely mounted on the end of the axle with four heavy bolts and a short piece of cable leading to conduit on the front

platform. This avoids gears, belts, pulleys, friction drive, etc. and allows accessibility. The generator is of the simplest possible construction: winding is stationary and leads are brought out to a small connection box to which the cable is also secured, so that shaft is kept from turning while outer part containing strong cobalt magnets rotates about the winding and generates a voltage and frequency proportional to speed. There are no brushes or commutator. Magnets are carefully aged, will not change their strength under most severe service conditions, it is said. Indicating instrument mounted in cab is calibrated in miles per hour. Movement bearings have extra-large jewels and pivots to withstand severe vibration. For use on steam locomotives, entire mechanism is surrounded by $\frac{1}{4}$" sponge rubber and mounted in a heavy brass case.—*Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

Multiple-ratio Transformers

"Unitap" transformers present a convenient means of providing a selective potential for laboratory and field testing purposes. Each unit consists of a multi-tapped transformer, with leads brought out to plainly-marked positive-contact plug-in terminals. Transformers are designed with liberal copper and iron densities and give an almost continuous scale of secondary potentials. Any range can be furnished up to 5000 volts and up to 3-kva. capacity, with any size steps. Two stock types are furnished, both varying the potential in one volt steps from 110-120 volt lines at 60 cycles:

No. 4344 is a 120-va. unit, having two plug-in sections: one for unit steps, with 10-amp. capacity, the other for 10-volt steps, with 5-amp. capacity from 0 to 20 volts, 2-amp. capacity from 20 to 50 volts, and 1-amp. capacity from 50 to 120 volts. Line is tapped at 110-115-120 volts.



No. 4345 (illustrated) is a 330-va. unit having three plug-in sections: one for unit steps, with 10-amp. capacity, one for 10-volt steps, with 5-amp. capacity from 0 to 20 volts, 2-amp. capacity from 20 to 50 volts and 1-amp. capacity from 50 to 100 volts; the third for 100-volt steps, with 3000-milliamp. capacity throughout.

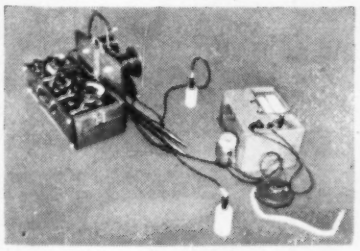
Transformers, mounted in cast aluminum frames bolted to Bakelite engraved panels, may be removed from the case for panel mounting. Each instrument is furnished complete with both line and load cables and all jumper plugs color coded to prevent errors in operation.—*H. F. Miller Co., Trenton, N. J.*

Portable Pyrometer

New "Model 622" millivoltmeter thermoelectric pyrometer, superseding well-known "Model 322" after many years, embodies improvements and refinements among which a 25% increase in scale length (now 5½") is most obvious of outwardly-visible. In new double-pivoted millivoltmeter movement, use of cobalt magnet and complete shielding are principal refinements. Coil (resistance now 116 ohms) is designed for 20.9 ohms per millivolt. Scales are available for temperature ranges up to 3000°F., are calibrated for iron-constantan, chromel-alumel or Pt *vs* Pt-Rh thermocouples. Greater sensitivity has been attained without sacrificing ruggedness and without need of critical leveling adjustments. Automatic cold-junction compensator is of bi-metallic type. Molded Bakelite case measures 8"×7½"×4½" high when closed, is of moisture- and dust-proof construction. Though of laboratory grade, new pyrometer has been developed for severe industrial service, is available in double-range models. —*The Bristol Co., Waterbury, Conn.*

Earth Exploration Devices

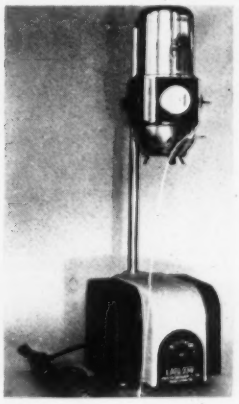
For subsurface earth explorations by electrical methods, the Shepard Earth Resistivity Meter and the Lee Geoscope are announced. They are said to provide a rapid and inexpensive means of conducting subsurface explorations such as locating depth and subsurface contours of rock strata, gravel beds, clay, shale, ore bodies, etc., being applicable to any depth from 3 to 2500 ft. Through use of Shepard Meter, engineers of U. S. Bureau of Public Roads have developed



a rapid technique that enables a crew of only two engineers and two assistants to make from 10 to 20 shallow tests in one day. The Lee Geoscope is now in use by U. S. Bureau of Mines. Method is said to result in great saving of time over the old test drill method. —*American Instrument Co., Inc., 8010-8030 Georgia Ave., Silver Spring, Md.*

Monochromatic Light Source

"Lablamp," a new monochromatic light source for spectrophotometric, refractometric, microscopic and polarimetric measurements, has an output of 3500 lumens of visible light, an efficiency twice that of an ordinary 500-watt incandescent lamp. Its effective light source is concentrated in a $\frac{1}{10}" \times \frac{1}{2}"$ space, making it especially useful in optics and spectrographic work. A small quartz tube surrounded by a hard glass

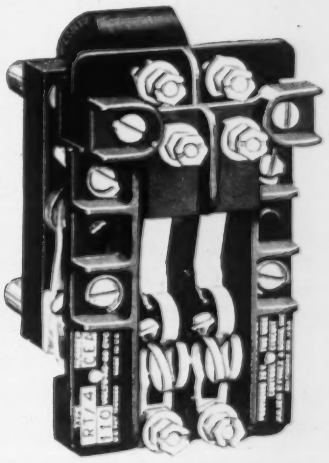


envelope absorbs most light below 0.32 microns in wavelength (ultra-violet), the latter being available, however, by removing the glass envelope. Of the total radiation, 25% occurs in visible spectrum, as compared with 5% in the incandescent lamp. Only 1.9% of output occurs between 0.60 and 0.76 microns as compared with 27% in the incandescent lamp. Lamp housing is adjustable to any angular position in a horizontal plane, and at any height from 5¾" to 20" from bottom of base. Doors on three sides of lamp housing are easily slid out and replaced by monochromatic filters for isolating the various spectral lines of mercury radiation. Operates on 110-120 volts, 50-60 cycles a.c., also on d.c. when used with suitable converter. Rated at 95 watts together with reactor. Weight, 14 lbs., measures 5¼"×6½"×17" high. —*American Instrument Co., Inc., Silver Spring, Md.*

Temperature or Pressure Controllers

New "Type RM Temperature and Pressure Control" is a combination of an auxiliary switch mechanism, operated by a temperature or pressure bellows, and a magnetically operated contactor. The auxiliary contacts require "very little" power for operation, making possible a "very low" differential. Main contacts are closed by the magnet under "heavy" pressure with "quick" make and break, providing current-carrying capacity of 1 h.p., 110-220 volts a.c., 1 h.p., 115-220 volts d.c. Available in temperature ranges from —20° F. to +90° F. Differential is adjustable up to 7° and down to less than 1°. Overall dimensions 2½"×3⅝"×2½". BX, or conduit outlets, are provided on top and bottom of control directly in line with terminals. —*Ranco, Inc., Columbus, Ohio.*

Something Really NEW To Write Us About!



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Transformer is built right into the Relay

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A.S.T.M., Laboratory and Industrial Thermometers

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Vapor-proof "All-position" Plunger-actuated Switch

New "HC Sealed Switch" is said to possess a combination of characteristics heretofore unobtainable in one switch: It is vapor-proof; operates in any position without being affected by the degree of vibration or tilting usually met with in service; and can be operated "well above the boiling point of water without deterioration." *Operating Characteristics:* Load required to make contact in the switch is an initial pressure of 10 oz. on plunger; contact being returned to its normal position when 2 oz. of this load are released. Thus a net load of 2 oz. is required to make or break. This is accomplished by moving plunger 0.002". Usual method of mounting is to hold switch in a metal clamp, pivoted at one end and placed against a spring at other so that its position may be varied by an adjusting screw with respect to movement applied to it. Loads and movements other than those mentioned can be supplied for special operating conditions. *Construction:* Housing is of molded Bakelite, vulcanized together by heat-treating. Plunger, working on beryllium-copper diaphragm, is of laminated Bakelite. Contacts are all of pure silver faced on pure copper, thus providing an oversized contact area with ability to dissipate heat rapidly. All parts are designed with generous safety factors. *Electrical Data:* "Type A" switches are designed for 10 amps at 110 volts a.c. or 5 amps at 220 volts a.c. either 50 or 60 cycle. Heating and lamp loads rated slightly higher for normally-closed switch than for normally-open. Loads exceeding 200 watts d.c. require use of capacitors (available). *Heineken Machinery Corp., 95 Liberty St., New York City.*

All-wave Power-line "Filterette"

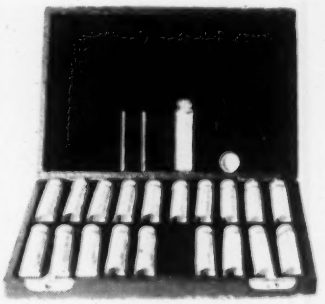
Providing 60-db attenuation of frequencies between 200 kc. and 30 Mc., new power-line "Filterette Model TR25" effectively isolates receiver and instrument test rooms from high-frequency disturbances present on electric power circuits in factory and industrial areas, makes possible testing at full sensitivity on all bands. It is designed to operate on any 110-volt, single-phase circuit and will handle 25 amps, it is said, without excessive heating or voltage drop. Complete specifications for construction of an effectively shielded test room are supplied with the device. — *Tobe Deutschmann Corp., Canton, Ohio.*

Source of Artificial Daylig

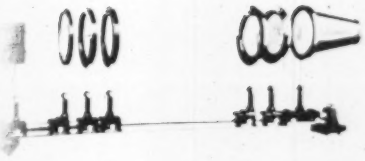
This new line of artificial da... lamps differs from the usual type ... binations of incandescent bulbs ... filters, said to be "subject to vari... because of voltage changes and ... life") in that the illumination is d... an electric discharge in carbon di... Variation of current affects only in... sity of emitted light and not its ... tive spectral distribution. Of the ... mon gases, carbon dioxide has a den... filled, well-balanced spectrum wi... luminosity distribution close to that ... cloudy north sky light, or average ... light, which is the accepted standard. While carbon dioxide lamps resemble neon tubes, there are essential differences: CO_2 becoming extremely active when ionized, it necessitates use of special electrodes and means of replenishing the gas. The pressure range for satisfactory operation is about one one-hundredth that of neon. An electronic pressure-regulating system (called "Baratron") has been developed, which can, by the way, be adapted to other low-pressure-control applications. (0.1 mm. Hg.). Chromatically of CO_2 radiation remains unchanged throughout life of tube due to continuous supply of fresh gas; and it remains unchanged with ordinary changes in line voltage. New CO_2 lamps are available in several shapes and wattage sizes. One typical model consists of 25 feet of 25-mm. tubing bent back and forth in the form of a grid, affording a uniform and glareless light source 3 sq. ft. in area. A current of approx. 0.2 amp. is supplied by a standard luminous-tube transformer; power consumption is 600 watts. Lumens-per-watt efficiency, though not as high as that of most gaseous-discharge lamps, is however higher than that attained with filtered incandescent daylight lamps. New lamps have a guaranteed life of 5000 hours. *Backus-Frink Tube Lighting Corp., Long Island City, N. Y.*

Gear Measuring Wires

A new system of gear wires, suitable for measuring the pitch diameter of either 14½° or 20° involute gears of any number of teeth from 9 to 200, simplifies calculations, being based on formulae given by Buckingham in his book "Spur Gears." The system involves the use of



a series of wires which are inversely proportional to the diametrical pitch, tooth factors for each different numbers of teeth from 9 to 200, and values of Cos 90° for use in measuring gears with odd numbers of teeth. Complete formulae and tables showing how to make pitch diameter measurements are furnished with the new set of gear wires. *The Van Keuren Co., 14 Copeland St., Watertown, Mass.*



Photoelastic Polariscope

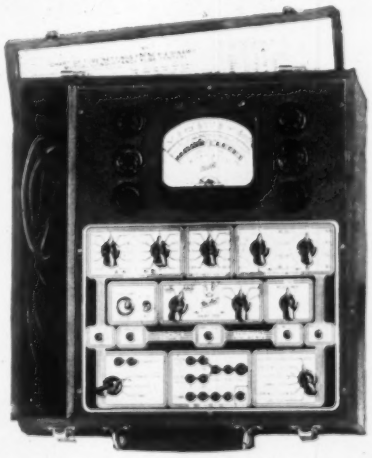
A large-aperture photoelastic polariscope, using "Polaroid" as the polarizing element, comprises the following:

(1) Light source.
(2) Collimating lens.
(3) Polarizer in rotating mount with scale for 180°.
(4) Quarter-wave plate in rotating mount with scale for 90°.
Ample space is allowed for a loading frame.
(5) Quarter wave plate in rotating mount with scale for 90°.
(6) Analyzer in rotating mount with scale for 180°.
(7) Projection system.

The apparatus is regularly made up in three standard sizes: 4¼", 6¼" and 8¼" aperture, although special sizes up to 12" aperture are available. For those who wish to construct their own apparatus, makers will make available any parts which one may require. *Polarizing Instrument Co., 8 West 30th Street, New York City.*

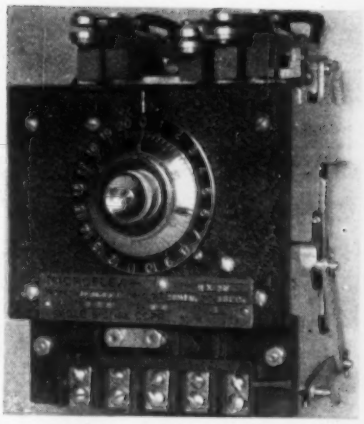
Tube Tester

New "Model AC-51X" is a combination tube tester measuring mutual conductance of all radio tubes. It indicates volts, ohms, milliamperes, output, microfarads, capacity leakage and decibels.



As a tube tester it is dual reading, one scale is marked "poor" and "replace" while the other is graduated on micromhos of mutual conductance. It also indicates the amount of hum in filter systems and checks the inductance of chokes with or without the d-c. component of current. The a-c. volt-meter is said to be accurate on all commercial and audio frequencies. The ohmmeter uses no batteries, operates from the built-in power pack. Indicating instrument is a Hickok-built d'Arsonval type, scale length >4", etched dial with color grouping of ranges. Same scale is used for a-c. and d-c. volts, and it is uniform. No copper oxide rectifiers are used, all rectification being accomplished by vacuum tube circuits. Case is rubber walnut, operating panel is etched chromium finish. All necessary leads are furnished.

The Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.

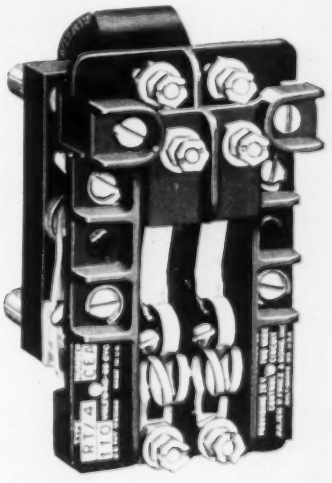


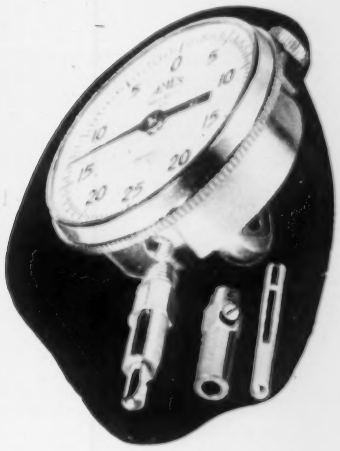
Flexible Process Timer

New "Microflex" Timer is of type referred to as "instantaneous reset timer": in a normal cycle of operation it opens or closes a control circuit at the end of a definite interval following opening or closing of its pilot circuit, and then resets instantly. Outstanding feature is said to be unusually wide range of time adjustment. Among available models are four, each having a range of 600 to 1. In one model, a laboratory instrument, range is from 0.2 second to 120 seconds with an accuracy of 0.1 second over entire range. In another, range is from 2 seconds to 20 minutes with accuracy of 1 second; in another, from 12 seconds to 2 hours with accuracy of 3 seconds; in the fourth, from 2 minutes to 20 hours with accuracy of 1 minute. Adjustments are accomplished by rotating a dial on face of timer. Contacts are rated 15 amps. at 110 volts. *Eagle Signal Corp., Moline, Ill.*

Relay-transformer Sets

New electrical relay-transformer sets are said to be based upon a recent discovery said to make it possible to obtain relays for handling loads up to ¾ h.p. or 1000 watts "and at the same time a transformer at a cost no higher than for a simple relay alone." Load to be handled remains on line voltage (which may be either 110 volts or 220 volts) while control instrument (thermostat, humidistat, etc.) is placed on low voltage. In this new design the same coils which operate the relay itself also produce the low voltage supply (20 volts). *Julien P. Friez & Sons, Inc., Baltimore & Central Aves., Baltimore, Md.*



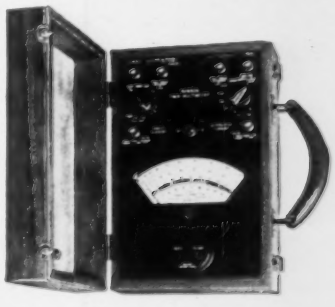


EASILY CLEANED

The case stem of the Ames Shockless Gauge can be easily unscrewed, the lower half of the spindle withdrawn for cleaning and the assembly replaced without otherwise disturbing the gauge. For details of other exclusive features, send for the Ames Gauge catalogue.

AMES *Shockless* GAUGES
B. C. AMES COMPANY
WALTHAM, MASS.

Rawson Twin Multimeter



29 ranges in less space than any near equivalent combination—
size 12" x 8" x 6"

RANGE OF MEASUREMENTS

D.C. 1 microampere to 1 ampere
25 microvolts to 1000 volts
A.C. [illegible]
2 milliamperes to 3 amperes
10 milliohms to 1000 megs

List Price $165.00

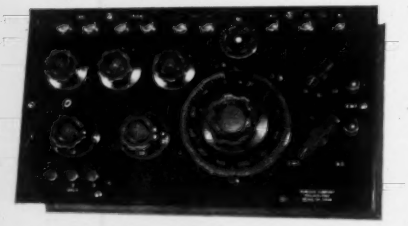
The Rawson measuring instruments are the only ones having two pivot movements whose weight is lifted from jewels when clamped for transit. Electrical clamping does not accomplish this purpose.

[illegible]

RAWSON Electrical Instrument Co.
CAMBRIDGE, MASS.
New York — Special Apparatus Built to Order — Chicago

TYPE B

Potentiometer



A standard laboratory potentiometer with 5 ranges: 1.6 volt, 160 millivolts and 16 millivolts.

These 5 ranges cover the entire field in which the potentiometer method is applicable, including the calibration of meters and potentiometers, the measurement of hydrogen-ion concentration and the accurate measurement of temperature with thermocouples.

This is a highly accurate and convenient instrument used in leading college, research, and standardizing laboratories.

Ask for Bulletin No. 270

RUBICON COMPANY

Electrical Instrument Makers

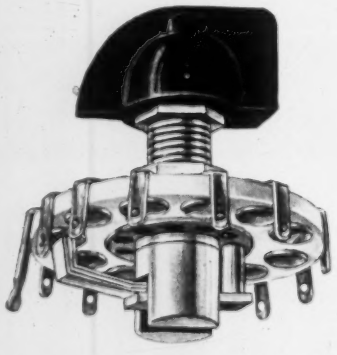
29 North Sixth St. Philadelphia, Pa.

SHALLCROSS

INSTRUMENT SWITCHES

Single and Double Deck

High grade, inexpensive rotary switches employed in instruments for the selection of ranges, tapping resistances, transformers, laboratory test equipment, decade boxes, Wheatstone Bridge circuits, and many other uses.



These switches are so designed that either brass or silver contacts may be furnished, shaft insulated, shorting or non-shorting and many other modifications.

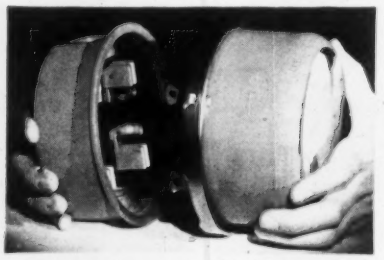
Send us your switch specifications. Write for Bulletin 530-HA for details and prices.

SHALLCROSS MFG. CO.

COLLINGDALE, PA.

Plug-in Instruments

A new system of detachable instruments whose sockets may be cut into conduit, or grouped in standard metal boxes to constitute a panel assembly, is announced for general industrial purposes. Each detachable instrument consists of: (1) a socket unit provided with electrical connection jaws; (2) instrument unit mounted on plate having electrical connection blades on the back. Sockets can be installed in all circuits feeding electrical loads in industrial plants and processes where it may be desired even if only occasionally to know consumption and performance characteristics. Socket provides its own switchboard, eliminating panels, wiring and mounting details. Various instruments can be plugged in same socket to



obtain volts, amperes, watts, power factor, kilowatt hours, etc. Sockets can be installed and sealed off, providing convenient outlets for future installation of instruments or making connections for portable analyzers for periodic testing.

Socket Unit is available with either two or three threaded outlets to receive $\frac{3}{4}$", 1" and 1$\frac{1}{4}$" pipe conduit, or with breakouts in the back. It is equipped with terminal blocks fitted with solderless terminals for connection of the incoming and outgoing wires. Terminal blocks carry heavy-duty jaws for receiving the switch-blade connections on back of instrument base. Standard sockets are announced in a wide variety of styles, including vertical and horizontal arrangements, two depths, with or without breakouts in the back, three sizes of conduit and with or without circuit closing devices.

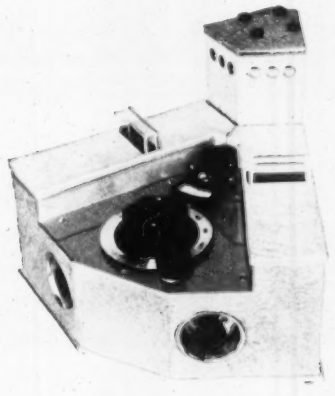
Instrument Unit consists of a standard switchboard instrument dial and movement mounted on a base plate. All internal connections are permanently made to base plate at factory. Base plate is equipped with heavy-duty connection blades to fit jaw receptacles in socket. Instrument unit is enclosed with an extra-strong annealed glass cover held to base plate with a metal band having receptacles which slide on to lugs on base when giving cover unit a slight turn. Glass cover exposes entire dial and pointer. Operation of plugging instrument into socket automatically completes connections from socket to instrument. Instrument is sealed to socket with a grooved ring, fitting over a flange on both instrument and socket, making entire unit dust- and weather-proof. To remove instrument, sealing ring screw is loosened and sealing ring removed; instrument may then be pulled from socket without disturbing permanent wiring.

Trough Installations. Where it is desired to install one or a few instruments for various forms of circuits, a metal trough is available equipped with socket units. All wiring is made to and from the trough by conduit. The necessary instruments are plugged into the sockets in front of trough. Among advantages are convenience and all parts readily available for a quick installation.

Ratings. Detachable 7" instruments (5$\frac{1}{4}$" scale length, 1% accuracy) are available in a-c. ammeters self-contained up to and including 25 amps. For larger currents a current transformer is used with a 5-amp. detachable instrument. Single-phase and polyphase wattmeters are available self-contained up to and including 20 amps. and 115 volts. For higher ratings current transformers are used, and the potential circuit for higher voltages is supplied with external resistors or transformers. D-c. ammeters are available up to and including 30 amps. self-contained beyond which a line of "Type G" shunts is available for larger currents using a 50-millivolt d-c. ammeter. A line of both d-c. and a-c. voltmeters is also provided in ranges from 150 to 750 volts self-contained d-c. and 150 to 600 volts self-contained a-c. *Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

Abridged Spectrophotometer

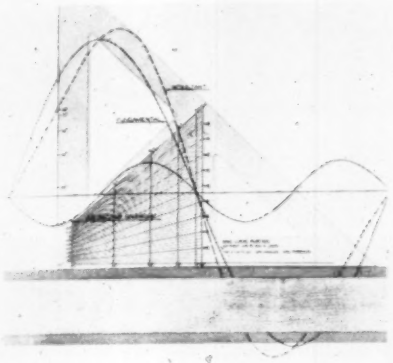
New Aminco Type "V" Photometer, an abridged photoelectric spectrophotometer, is said to be adapted to almost any chemical analysis where colorimetric methods may be developed. When furnished with an 85-watt mercury-vapor lamp and suitable filters it isolates the various lines of mercury radiation. For work involving wavelengths that cannot be obtained from a mercury-vapor lamp, Aminco Photometer can be used with a 50-watt incandescent lamp and suitable filters for isolating the wavelength bands that are needed. Even with no filters, this instrument is said to be more sensitive to color intensity difference than the human eye, and gives more surely



reproducible results than can be obtained with most visual colorimeters. For general laboratory use, the Aminco Photometer, equipped with a double set of red, yellow, blue, green and violet filters, is said to be more accurate and adaptable than a visual colorimeter, and when once calibrated for a particular material the calibration is said to be permanent and there is said to be no necessity for making up standard solutions when instrument is used on same material later. For use on 110-120 volts, 50-60 cycle a.c., also for d.c. when used with suitable converter. Weight, 16 lbs., measures 13" × 13" × 9" overall. *American Instrument Co., Inc., 8010-8030 Georgia Avenue, Silver Springs, Md.*

Sine Curve Plotter

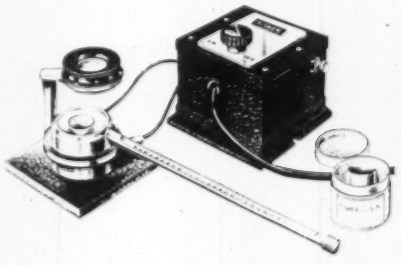
...d to fill need long felt by electrical ...echanical engineers for an instru... which would directly plot the ...s on a sine or cosine curve. By ...s of the Sine Curve Plotter a sine ...sine curve may be "completely plot... in a few seconds." All time-consum... construction lines associated with the ...entional graphical method are elim...d. The Plotter is simply a chart in...ed on a 10", 45° drafting triangle.



It will produce curves of any percentage amplitude. To use Plotter, triangle is placed over curve axis such that particular interesting lines on the chart lie over points on curve axis (in accordance with the point on the cycle and the percentage amplitude in question) and a dot is made at a corresponding left-edge graduation of triangle. Triangle is moved along axis and other points similarly plotted until curve is completely located. Ordinates may be plotted at intervals as close together as 15° on the cycle axis, if desired, thereby producing highly accurate contour. Although sine and cosine curves are relatively displaced in phase they are exactly the same shape, so the Plotter is equally efficient for locating curves of either type. Instrument is incorporated in a high-grade celluloid triangle to provide a device of double utility. A novel feature of the triangle is that intersecting 45° lines may be drawn without reversing triangle on board—a feature that lends itself to speedy drafting of machine threads, among many applications. *A. Lietz Co., 945 S. Grand Ave., Los Angeles, Calif.*

Melting Point Apparatus

New Fisher-Johns Melting Point Apparatus is said to be simple to operate; requires only a small sample for a determination. It consists of a cylindrical



aluminum stage, 2" diam. and about ¾" thick. On upper surface, exactly in center, is a circular depression covered by an 18 mm. round micro cover glass. Block is electrically heated by a resistance wire on lower side; temperature is indicated by a 300° C. thermometer with red column and magnifying front, its bulb extending into the block to a point directly under circular depression. Transformer furnished with apparatus permits stepless regulation of temperature. Observation magnifier with adjustable focus is permanently mounted on a brass standard but can be swung out of the way when not in use. Apparatus can be employed also as a hot plate for micro beakers (up to 50 cc.). With thermometer at 160° C. it will boil water in a 30 cc. beaker set on top. Apparatus is mounted on a base of insulating material. *Fisher Scientific Co., 709 Forbes St., Pittsburgh, Pa.*

Air-operated Control Valve

New "No. 350 Synchro-Flow" diaphragm-motor valve is said to represent a new development in the design and construction of valves for automatic control purposes. In the superstructure, usual sources of friction have been "entirely eliminated" by a new design of which the main feature is a universal ball joint. In the valve body, inherent friction due to velocity effects forcing disk-plug against side walls of seat rings or disk guides has been minimized by the new "Equipoise" design of which the main feature is a flow-diverting inlet.

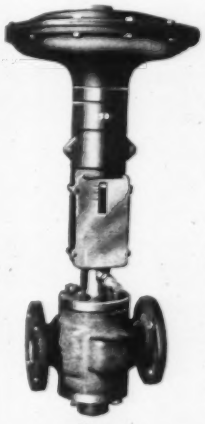


Fig. 1

The remaining source of friction—the stuffing-box—has been minimized by using (a) small-diameter, precision-ground and -polished, stainless-steel stems, (b) stem lubricator and (c) radiating-fin bonnet for applications where temperatures above 150° F. or below 32° F. might impair the properties of the

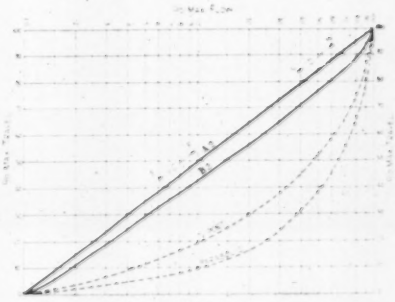


Fig. 2

packing. *Characteristics:* Maker has issued a graph, Fig. 2, showing generalized characteristics of "Type V2" and "Type B2" in comparison with V-port and parabolic types. Maker states that actual test results do not produce the absolutely straight line as drawn, but in general, equal percent increases in lift produce equal percent increases in flow. *Sizes:* Maker supplies, for purpose of valve selection, complete charts covering variables such as specific gravity, API gravity, degrees Baume, pressure, temperature, superheat, pressure drop, etc. *H. Belfield Co., 2nd & Somerset Sts., Philadelphia, Pa.*

A New SIGMA Relay

Type 2-A

A sensitive, rugged instrument for general electronic and industrial purposes.

Input, 12 milliwatts, D.C.
Hairspring adjustment.
Single-pole, double-throw.
Operable in any position at rated input.
Fine silver contacts handle non-inductive loads of 150 watts at 110 volts, A.C.
Mounted on 5-prong plug-in base fitting standard V.T. socket.

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2,000 ohm field and under . . . $5.00
5,000 and 8,000 ohm fields . . . $5.50

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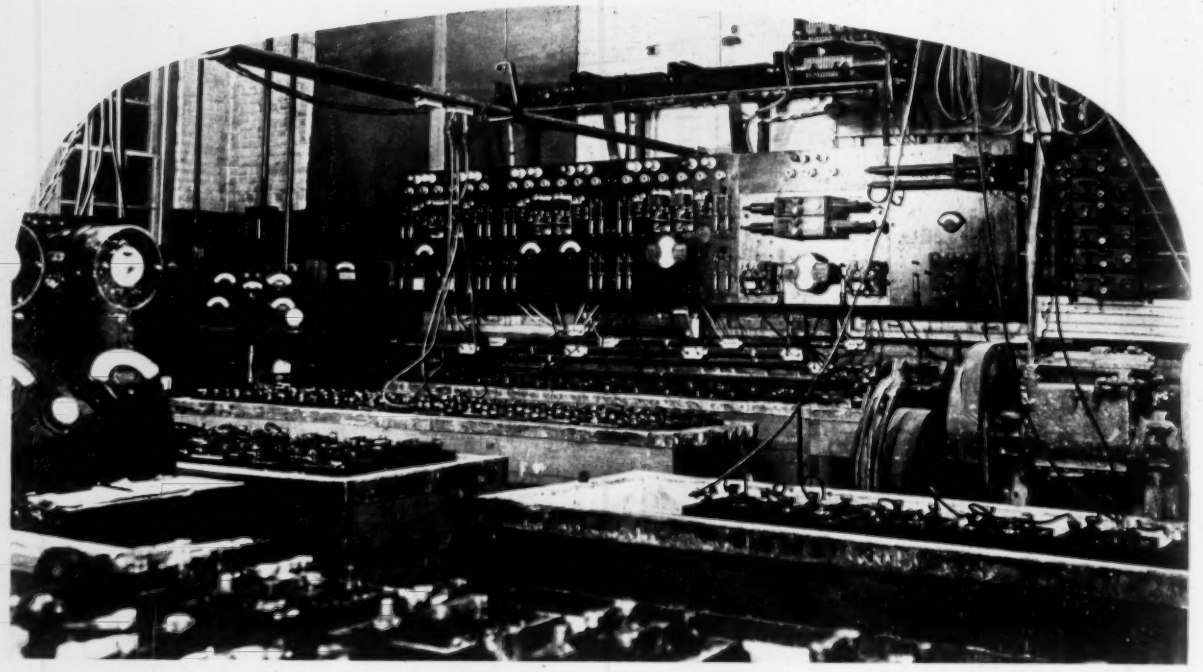

View across Storage Battery Research Test Room. Life test control panels and special discharge bench in background.

Storage Battery Life Tests

By H. R. HARNER, Chief Chemist, and J. E. HATFIELD, Ph.D., Battery Engineer,
Research Laboratories, The Eagle-Picher Lead Company, Joplin, Missouri

IN the manufacture and application of storage batteries, the development of a fully satisfactory laboratory life test is a major technical problem. Numerous life tests of three general types are in use but none is entirely satisfactory. The test described here is representative of the type in most general use and is the same in principle as the adopted life test of the Society of Automotive Engineers[1].

The only certain way one may learn the life characteristics of an automobile battery is to put a large number in all types of service and from the statistical study of the results decide whether the battery in question is better or worse than a comparison type battery. This is both a time consuming and expensive process. By the time results are gathered and analyzed the trend of the industry may have changed so that the type battery tested is obsolete. The development of a satisfactory laboratory life test is highly desirable so that only a few batteries need be tested and so that the test may be completed soon enough to be of value. A fully satisfactory life test will do the following:

1. Yield systematic results on systematic series
2. Yield duplicate results on duplicate batteries
3. Yield results comparable with actual service
4. Yield results quickly.

[1]Society of Automotive Engineers Handbook, 1936, pages 101-118.

Editor's Note: This is the first article in a series on the Testing of Storage Batteries, by authorities.

The present test fulfills requirements (1), (2), and (4) quite well, but only partially fulfills requirement (3). Results are obtained in eight to twelve weeks. The degree of duplication of results is shown in Fig. 1,

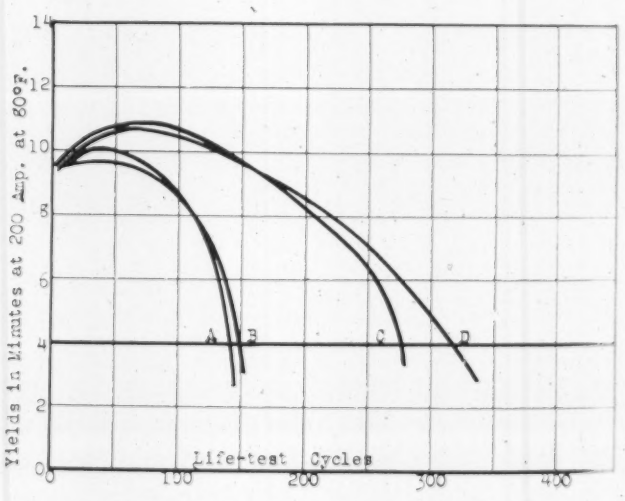

Fig. 1. Example of Duplication of Results.

where data from four original equipment batteries made by the same company are shown. Batteries A and B were made in 1932, while batteries C and D were made in 1934. It is evident from the results that the company in question made a decided improvement in the batteries during the interim.

...ttery service in general may be divided into two ... automotive starting, lighting and ignition (SLI); ...eavy-duty. Included in heavy-duty are farm-light, ...adio, telephone and telegraph, vehicle, locomotive ...marine batteries. All these services are similar in ... the batteries are subjected to a more or less regular ...ence of charge and discharge or cycles. Such serv... ...auses the same type of failure, namely grid corro... ...shrinkage of negative plate material and shedding ...positive plate material, obtained on tests similar to ...one described here, and hence these tests are directly ...ful.

Starting and lighting service is characterized by no ...h regular treatment. Cars are driven from a few ...housand miles a year in the case of "Sunday drivers" ...o hundreds of thousands of miles a year in the case of ...axicabs and commercial cars. The electrical demands ...nd relative overcharge are seldom the same in any two ...ars. Temperatures of use range from well above 100 F. ...o far below 0 F. Consequently the life of a single bat...tery in car service is almost unpredictable. Failure may ...ccur through complete oxidation of the positive grids, ...through shedding of the positive plate active material, ...or through buckling of the positive plates with conse...quent cutting of the wood separators and shorting of ...the cell. With the increasing use of thinner and lighter

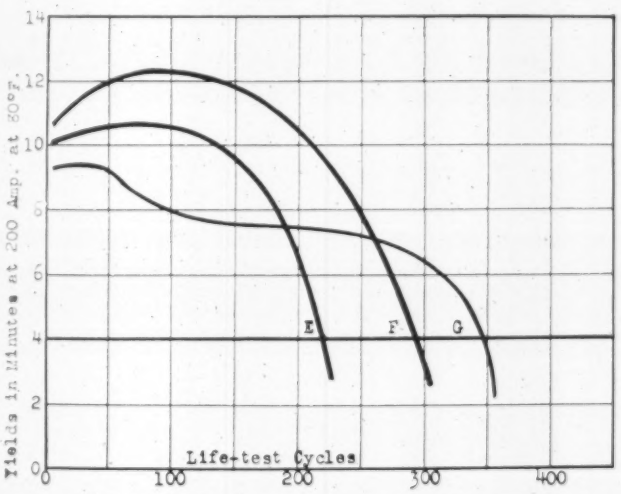

Fig. 2. Typical Commercial Battery Life Tests.

grids (but more plates to the cell) buckling is becoming less a factor than it was with the heavy grids formerly in favor.

As is evident from the above, most automobile battery failure is due to failure of the positive plates, and consequently laboratory tests are mainly tests of the positive plates. Occasionally batteries will fail in service because of hardening or shrinkage of the negative plate active material, but this is becoming quite uncommon by reason of recent improvements in negatives. This type of negative plate failure is brought out well by most types of laboratory tests.

The E-P test causes battery failure through positive grid oxidation, positive plate shedding, and shrinkage of poor negative plates just as does the similar S.A.E. test. Neither is entirely satisfactory in that buckling of the positive plates is never produced to such an extent as to cause battery failure, even in positives that would normally be expected to fail in service by buckling. Furthermore, such a positive will usually give an exceptionally good life test by these laboratory methods. In spite of this defect, and because of its good points previously enumerated, this general type of test is widely used today among battery manufacturers and among the suppliers of storage battery oxides.

Fig. 2, illustrates typical life tests of comparable batteries of standard 18-month warrantee construction from three different manufacturers. From the curves of Fig. 2 it is evident that this test not only gives an indication of the length of life but also an idea of the kind of service the battery will deliver during its life. Batteries E and F gave similar shape curves, with F definitely superior both as to capacity and as to length of life. Battery G gave longer life than either of the others but lower capacity during life. Knowing the companies producing batteries F and G, the answer is apparent. Bat

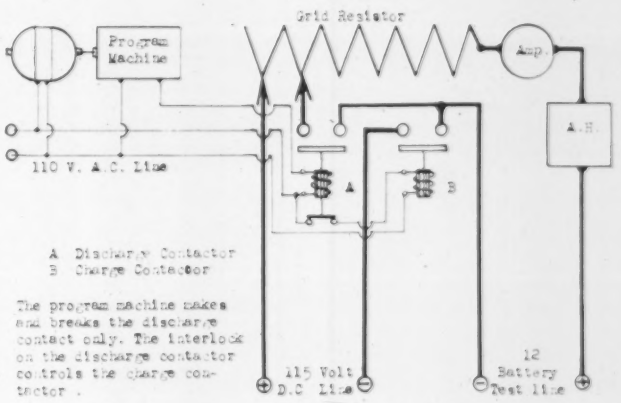

Fig. 3. Schematic Life-Test Wiring Diagram.

tery F is made for the extreme northern part of the country where very cold weather is expected in winter. Under these conditions a battery with lots of snap for quick starting is the primary requisite, with life a secondary matter. Battery G is made for the south where snap is not needed, but where long life is at a premium. Hence both batteries are well engineered for the sections of the country where they are made and sold.

The E-P test is an outgrowth of the life test proposed a number of years ago by the National Battery Manufacturers Association. The N.B.M.A. test called for two cycles per day, with the switches manually operated. To speed up the test, four cycles a day are now given, using the same ampere hours of charge and discharge per cycle and an automatic program machine (Fig. 4) times the cycles exactly without attention. Fig. 3 shows the schematic wiring diagram used, and this may be extended by more units as needed, ten such units (all operating from the same program machine in hourly sequence) being in use in the Eagle Picher storage battery laboratory.

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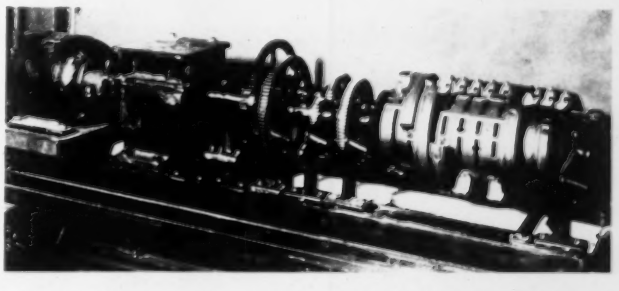


Fig. 4. Synchronous-motor-driven life-test program machine.

Flow Nozzle Research

Introduction—Program of A.S.M.E. Fluid Meter Committee*

By HOWARD S. BEAN

Senior Physicist, Chief of Gas Measuring Instruments Section, National Bureau of Standards;
Chairman of Sub-committee on Flow Nozzle Research, A.S.M.E. Special Research Committee on Fluid Meters

THIS research program on flow nozzles was undertaken at the request of the Power Test Code Subcommittee on the Measurement of Fluid Flows, as transmitted through the Main Power Test Code Committee. The reasons for this request were, on the one hand, that for the types of nozzles most used in this country the information that could be used as a suitable basis for acceptance tests was too scattered and meager; and on the other hand, that most users of flow nozzles do not favor the type of nozzle and connections used in Europe.

The form of nozzle being particularly studied in this program has been termed the "long-radius" nozzle, in contrast to the relatively short nozzle used in Europe which is frequently referred to as the I.S.A. or V.D.I. nozzle. For the purposes of this program the more important factors considered in defining the contour of the long radius nozzle were: That the forms of nozzles already in use and on which some test data were available should be considered; that the nozzles should be designed primarily for use in tests, *i.e.*, acceptance tests, since this was the basis for the request from the Power Test Code Committee; that commercial nozzles may not be made to be exactly the same shape, although there will be some advantages in doing so; that the total length of the nozzle should be great enough to permit the locating of the outlet or down-stream pressure tap well back (upstream) of the outlet end of the nozzle, yet with minimum interference with the pipe flange which holds the nozzle. Early in the discussion it was decided that the curve joining the flange and throat portions of the nozzle should be a quadrant of an ellipse. Later it was decided that the relations between the semi-major axes of the ellipse and the pipe and nozzle throat diameters should be as follows:

For $\beta < 0.50$

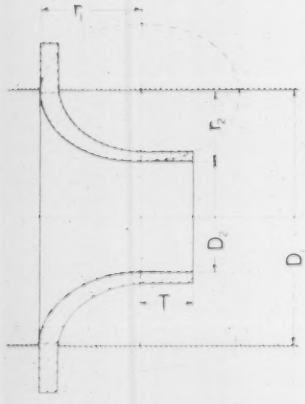
$r_1 = D_2$ $\quad r_2 = 2.3\,D_2$ $\quad T = 0.6\,D_2$

In the future this series will be referred to as the "Low β Series."

For $\beta > 0.40$

$r_1 = 1.2\,D_1$ $\quad r_2 = 1.2\,(D_1 - D_2)$ $\quad T = 0.6\,D_2$

This series will be referred to as the "High β Series."



In the above relations

$\beta = D_2 / D_1$,

D_1 internal pipe diameter,

D_2 diameter of the nozzle throat,

r_1 semi-major axis of ellipse generating the nozzle entrance curve,

r_2 semi-minor axis of generating ellipse,

T length of the cylindrical portion of the nozzle throat.

Some of the reasons for the dual relation as given for the low and high series are: The inlet surface of the lower ratio series ceases to meet the pipe wall at 90° above $\beta = 0.43$. It was believed by the Subcommittee that more nearly geometrically similar flow patterns would be obtained if the contour of the inlet section were made to intersect the pipe wall at about the same angle for all diameter ratios. This is achieved over the entire range by the two relations. Also, to use the first relation over the entire range would produce an undesirably long nozzle for the larger ratio sizes, while the use of second relation below a diameter ratio of 0.4 or 0.5 produces a nozzle with too much entrance surface. A third reason was that the first relation has been used to some extent in making nozzles for use in acceptance tests. For this reason the lower ratio nozzles are sometimes referred to as "test nozzles." On the other hand the second relation is much the same as one which has been used in some commercial measurements of fluids. The overlap of the two relations between $\beta = 0.4$ and 0.5 was provided to eliminate a sharp breaking point between them. Over this region the contours produced by the two relations are so nearly identical that noticeable differences in nozzle coefficients are not expected.

A number of the I.S.A. nozzles will be included in the research. The use of different pressure-tap locations will be studied in the case of all nozzles. In addition, most of the nozzles in the low-β series will have pressure openings in the throat of the nozzle.

For the purposes of designing the nozzles it has been convenient to assume D_1 equal to the nominal inside pipe diameter as given in such tables as Table 52 of the Report of the National Screw Thread Commission, 1933 revision. It always is necessary, of course, to measure the actual inside diameter of the pipe in which a nozzle is being used, in order to determine the exact diameter ratio.

The details of planning and carrying on the research program have been assigned to a subcommittee of which the writer is chairman. The funds and services with which the program is being carried on are being obtained through the solicitation of voluntary subscriptions by another subcommittee of which E. C. M. Stahl is chairman. The actual tests are being made in a number of different laboratories. One reason for this division of the testing is that no one laboratory has the facilities for making tests over the entire range of conditions included in the complete program. Another reason is that it provides a measure of the reproducibility of results which may be obtained between different laboratories, with their differences of personnel and equipment. The laboratories to which tests have been or will be assigned are:

National Bureau of Standards
University of California, Department of Mechanical Engineering
Cornell University, School of Civil Engineering
Lehigh University, School of Civil Engineering
Massachusetts Institute of Technology, Department of Mechanical Engineering
Ohio State University, Department of Mechanical Engineering
University of Oklahoma, School of Mechanical Engineering
University of Pennsylvania, College of Civil Engineering

From time to time, papers and reports dealing with various phases of the program will be published, some in *Instruments* and some elsewhere. The following article by Francis C. Morey is the first of this series. It describes the method used at the National Bureau of Standards to check the size and contour of the nozzles.

*Publication Approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

Determining Flow Nozzle Contours at Bureau of Standards

By FRANCIS C. MOREY
Junior Physicist, National Bureau of Standards

I. THE PROBLEM.

ONE of the problems assigned to the National Bureau of Standards in coöperating with the American Society of Mechanical Engineers' Fluid Meters Research Committee in their study of flow nozzles is the measurement of the nozzle diameters. From these data it can be determined how closely the nozzles as manufactured conform to the outline calculated from the nozzle design relations. Such measurements are of primary importance to users in judging the quality of fabricating processes, as well as in interpreting the coefficient data obtained by the laboratories.

The method adopted in checking the nozzle contours was developed by D. R. Miller, Chief of the Gage Section at the National Bureau of Standards, assisted by other members of that Section. After considering several other methods suitable for only limited ranges of sizes, the method described in this paper was selected because of its simplicity, accuracy and adaptability to all forms of the nozzles.

II. OUTLINE OF THE METHOD.

In brief, the method consists in placing the nozzle on its upstream flange surface on a surface plate through which extends an upright plug of known diameter and adjustable height. This plug is set to the height at which it is desired to check a diameter. The nozzle is moved over the surface of the plate, and the horizontal displacement, A, Fig. 1, along a diameter of the nozzle is found, from contact on one side of the plug to contact on the opposite side. This distance, added to the diameter of the measuring plug, gives the diameter at the selected height.

III. DETAILS OF THE EQUIPMENT.

A jig was built up to carry out these measurements. (Fig. 2 shows in part the apparatus with a nozzle for 3″ pipe in position for measurement.) A 5-ft. section of extra-heavy steel channel 7″ wide was planed off, to act as a surface plate. A hole slightly more than 1″ in diameter was drilled through the channel near the center. To the under surface a V block was attached, with its groove in such a position as to hold the cylindrical measuring plug projecting vertically through the hole in the surface. A clamp on the V block was provided to hold the measuring plug at any desired height. After assembling, shims were inserted between the channel and the V block and so adjusted that the axis of the measuring cylinder is held normal to the planed surface.

A 24″ vernier caliper was fastened to the left hand end, its movable jaw securely clamped to the channel, allowing the scale to slide through. A dial indicator, reading to 0.001″, was attached to the head of the vernier caliper with the button in position to contact the nozzle flange, and arranged to register horizontal displacements. Two measuring plugs were made, their nominal diameters being $\frac{3}{8}$″ and 1″ respectively.

IV. OPERATION OF THE MEASURING APPARATUS.

In operating the measuring jig, the plug is first set to the desired height by means of a height gage, dial indicator and Johansson gage blocks. The nozzle is then placed over the plug and moved to the right until it comes into contact with the plug. Then the vernier caliper scale is advanced until the dial indicator button contacts the nozzle flange. The nozzle is slipped back and forth at right angles to the vernier caliper, keeping its flange pressed firmly against the channel surface and maintaining contact between the curved surface and the measuring plug. During this operation the vernier caliper scale is further advanced so that the minimum reading of the dial indicator is brought to zero. In other words the dial is used as a null indicator. The reading of the vernier caliper is then observed.

Next the caliper is backed off, the nozzle is moved to the left into contact with the plug on the other side, and a second similar setting of the scale is made. In this case the null reading of the dial indicator is a maximum rather than a minimum. Care is used to see that the indicator button rests very nearly on the same spot on the flange as in the first observation. The difference in the vernier readings, plus the plug diameter, gives the nozzle diameter.

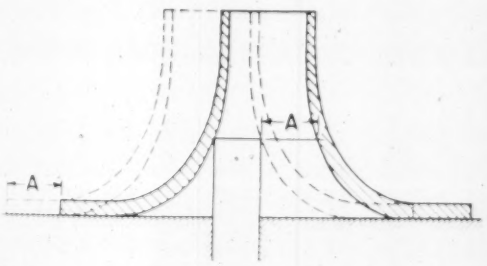


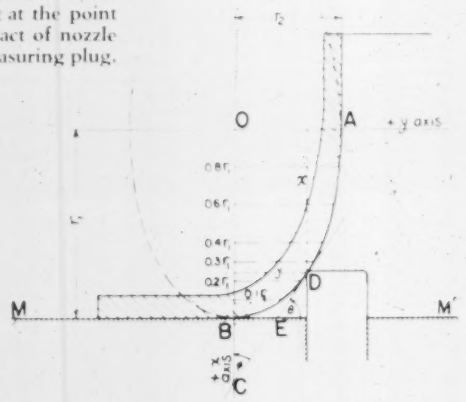
Fig. 1. Contact positions of nozzle, showing horizontal displacement.

Fig. 2. The measuring jig in use. At the right is the height gage and indicator, with Johansson gage blocks used to adjust height of measuring plug. The nozzle is in position over the plug, with the null indicator button in contact with flange.

V. CALCULATION OF CORRECTIONS.

It was found impractical to have sharp corners on the ends of the measuring plugs, since in use these cut or scratched the polished surfaces of the nozzles. It therefore was necessary to round the corners at the ends of the plugs as nearly as possible to true circular quadrants and to determine the radii of these curves. This necessitates corrections both on the height and diameter of the plug used, since its point of contact with the nozzle contour surface will lie below the top of the plug. In making the measurements the plug height correction is added to the height at which it is desired to check the diameter, and the plug is adjusted to this corrected position. It is thus possible to select any desired height of contact, and to compute the effective diameter the plug will have when so set. The methods of computing these corrections and of calculating the theoretical diameters will now be described.

Fig. 3. Illustrating the common tangent at the point of contact of nozzle and measuring plug.



(A) *Long-radius nozzles.*

Fig. 3 shows a section of a long-radius nozzle in contact with the surface plate MM′ and touching the measuring plug at point D. Let the origin of coördinates be at O, with OB and OA as the positive portions of the x and y axes, respectively. As explained in the introduction, the nozzle surface is formed by revolving a quadrant of an ellipse about the axis of the nozzle. There are two series of nozzles, known as the low-β series and the high-β series, based on the ratio of the throat diameter to the pipe diameter. Denoting the pipe diameter by D_2, and the throat diameter by D_1, $\beta = D_1/D_2$. The defining equations for the two series of nozzles are given in the introduction, and will be repeated as needed in this article.

In Fig. 3, let the semi-major and semi-minor axes be r_1 and r_2 respectively, and let the coördinates of the point of contact D of the curved surface ADB with the measuring plug be x and y. It is now desired to find the angle θ between the surface plate and the common tangent at the point of contact, in order that the necessary corrections may be computed.

The equation of the ellipse with center at the origin is

$$r_2^2 x^2 + r_1^2 y^2 = r_1^2 r_2^2 \quad . \quad . \quad . \quad (1)$$

Differentiating (1) gives

$$2r_2^2 x\,dx + 2r_1^2 y\,dy = 0$$

$$dy/dx = -(r_2/r_1)^2 (x/y) \quad . \quad . \quad . \quad (2)$$

Since the derivative is the tangent of the angle between the positive portion of the x axis and the tangent to the curve, and since $\tan\phi = -\tan(180 - \phi)$, it is evident that

$$\tan\phi = (r_2/r_1)^2 (x/y) \quad . \quad . \quad . \quad (3)$$

But since ϕ and θ are complementary angles

$$\text{Cot}\,\theta = (r_2/r_1)^2 (x/y) \quad . \quad .$$

Solving equation (1) for y gives

$$y = (r_2/r_1)\sqrt{(r_1^2 - x^2)} \quad . \quad .$$

which enables us to express equation (4) in terms of x and constants only

$$\text{Cot}\,\theta = (r_2/r_1)^2 \frac{x}{(r_2/r_1)\sqrt{(r_1^2 - x^2)}}$$

or

$$\text{Cot}\,\theta = (r_2/r_1)\, x/\sqrt{(r_1^2 - x^2)} \quad . \quad . \quad . \quad (6)$$

If now we elect to check the nozzle diameters at certain fractional heights, as $0.1r_1$, $0.2r_1$, etc., we can further simplify equation (6) for these positions, and in the case of the low-β ratio series we can even numerically evaluate the result. Tables I and II give these data.

The factors given in Table I can be used to compute the corrections applied in measuring all long-radius nozzles. However, since the semi-axes of the low-β series are defined by the relations

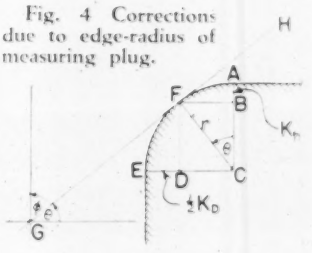
$$r_1 = D_2 \qquad r_2 = 3/2\, D_2 \quad . \quad . \quad . \quad (7)$$

the ratio r_2/r_1 is constant for this series regardless of the size of the nozzle. Thus Table II presents the values of the cotangents and of the corresponding angles, for all low-β series nozzles.

To obtain the height and diameter corrections let F, Fig. 4, be the point of contact of the plug on the nozzle, and let GH be the tangent common to the plug and the nozzle at that point. Denote by K_h the correction AB to be added to the height of the point of contact to obtain the true height of the top of the plug. Let the radius of the edge of the plug be r. Angle ACF is θ, determined from Table I or Table II. Hence

$$K_h = AC - BC$$
$$= r - r\cos\theta$$
$$= r(1 - \cos\theta) \quad . \quad . \quad . \quad (8)$$

Fig. 4 Corrections due to edge-radius of measuring plug.



Similarly, letting K_d be the correction to be subtracted from the plug diameter to give the effective plug diameter,

$$ED = \tfrac{1}{2} K_D = EC - DC$$
$$= r - r\sin\theta$$

$$K_D = 2\,r(1 - \sin\theta) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

Since θ is completely determined for each height for the low-β ratio series, Table III gives the actual cor-

TABLE I. VALUES OF $x/\sqrt{(r_1^2 - x^2)}$ AND ITS LOGARITHM, FOR LONG-RADIUS NOZZLES.

Height of contact	x	$\sqrt{(r_1^2 - x^2)}$	$\frac{x}{\sqrt{(r_1^2 - x^2)}}$	$\log\frac{x}{\sqrt{(r_1^2 - x^2)}}$
$0.8\,r_1$	$0.2\,r_1$	$0.97980\,r_1$	0.20423	9.31012–10
$0.6\,r_1$	$0.4\,r_1$	$0.91652\,r_1$	0.43654	9.64002–10
$0.4\,r_1$	$0.6\,r_1$	$0.80000\,r_1$	0.75000	9.87506–10
$0.3\,r_1$	$0.7\,r_1$	$0.71414\,r_1$	0.98020	9.99132–10
$0.2\,r_1$	$0.8\,r_1$	$0.60000\,r_1$	1.33333	0.12494
$0.1\,r_1$	$0.9\,r_1$	$0.43590\,r_1$	2.06470	0.31486

TABLE II. VALUES OF θ FOR LOW-β SERIES NOZZLES ONLY.

Height of contact	Cot θ	θ
$0.8\,r_1$	0.13616	82° 15′
$0.6\,r_1$	0.29103	73° 42′
$0.4\,r_1$	0.50000	63° 26′
$0.3\,r_1$	0.65357	56° 50′
$0.2\,r_1$	0.88889	48° 21′
$0.1\,r_1$	1.37647	36° 0′

tions applied to the measuring plugs used with the paratus. The smaller plug has a diameter of 0.3759" d an end corner radius of 0.010", while the larger is 1.0005" in diameter and has a radius of 0.034" its end. For the high-β ratio series a graph giving corrections has been prepared for each plug size, and ter computing the values of θ from Table I the cor- ctions may be read directly from the chart.

B.) *I.S.A. Nozzles*

To determine the corrections for measuring the I.S.A. nozzles a similar table may be prepared. Fig. 5 shows the principal dimensions and relations of the I.S.A. form. Arc BGE has its center at O and radius 1/3 D_2. At E the curvature changes and continues from center C with radius 2/10 D_2. Hence OC equals 2/15 D_2. Point C is completely determined because AB is made 1/4 D_2.

The total height of the curved surface will first be computed.

$$AD = CD + AC$$
$$= 0.2\ D_2 + \sqrt{(2/15\ D_2)^2 - (1/12\ D_2)^2}$$
$$= 0.30408\ D_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

This enables us to compute the desired heights of the points of contact. It can easily be shown that for the first position, 0.1 AD, the contact falls on the arc DE, of radius 2/10 D_2; but that for position 0.2 AD and higher, it falls on the larger arc EGB.

From Fig. 6, for the first position, 0.1 AD = 0.030408 D_2

$$\text{Cos } \theta = \frac{LC}{CM} = \frac{CD - LD}{CM} = \frac{0.2\ D_2 - 0.030408\ D_2}{0.2 D_2}$$

$$\text{Cos } \theta = 0.84796$$
$$\theta = 32^\circ\ 1'$$

For the other positions, referring again to Fig. 5,

$$\text{Cos } \theta = \frac{IG}{OG} = \frac{0.30408\ D_2 - 0.30408\ nD_2}{1/3\ D_2}$$

where n = 0.2, 0.3, 0.4, 0.6 and 0.8, successively, denoting the position.

$$\text{Cos } \theta = 0.91224\ (1 - n) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

Table IV applies only to I.S.A. nozzles with β less than 0.67, because, with larger diameter ratios, the pipe wall encroaches on the curve of smaller radius as can easily be seen from the geometrical relations shown in Fig. 7. This makes it necessary to set the plug lower than would otherwise be the case, since the fractional heights are still computed from the length DA. To find this correction, DQ, note that

$$PQ = RA - \tfrac{1}{2} D_1$$
$$= \tfrac{1}{2} D_2 - \tfrac{1}{4} D_2 - \tfrac{1}{2} D_1$$
$$= \tfrac{3}{4} D_2 - \tfrac{1}{2} D_1$$
$$= \tfrac{3}{4} D_2 - D_2 \frac{2\beta}{2}$$
$$PQ = 1/2\ D_2 (3/2 - 1\ \beta) \quad . \quad . \quad . \quad . \quad (12)$$

$$\sin \phi = \frac{PQ}{PC} = \frac{1/2\ D_2 (3/2 - 1\ \beta)}{2/10\ D_2} = 5/2 (3/2 - 1\ \beta) \quad (13)$$

$$QD = DC - QC = 0.2D_2 - 0.2D_2 \cos \phi$$
$$= 0.2D_2 (1 - \cos \phi) \quad . \quad . \quad . \quad . \quad . \quad (14)$$

Equations (13) and (14) make it possible to compute the corrections to be subtracted from the plug settings. The reliability of such measurements is somewhat questionable, since in making the nozzle it is difficult to face off the nozzle flange to exactly the right distance, DQ. In some cases, however, errors of this kind have been revealed by the measurements. Obviously if the diameters as measured are all too large, facing off more of the flange would bring the nozzle contour more nearly into accord with the specifications. If the diameters are all too small, too much metal has been removed. On the other hand, measuring from the mouth of the nozzle probably would be no better, because of larger tolerances allowed on the length of the throat.

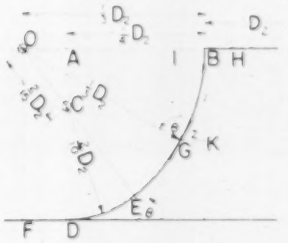


Fig. 5. Principal dimensions and relations of I.S.A. form.

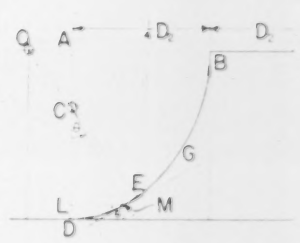


Fig. 6. Relations used in computing corrections for I.S.A. nozzle measurements.

VI. CALCULATION OF DIAMETERS.

(A) *Long Radius Nozzles.*

As previously explained the diameter measurements are made with the measuring plug so adjusted that the height of its point of contact with the nozzle above the surface plate will be in simple fractional ratios with the semi major axis of the generating ellipse. We will now proceed to develop equations by means of which the

TABLE III. VALUES OF CORRECTIONS AND OF EFFECTIVE PLUG DIAMETERS FOR LONG-RADIUS NOZZLES, LOW-β RATIO SERIES ONLY.

Height of contact	θ	Small plug r = 0.010" Kb	Kb	Eff. diam.	Large plug r = 0.034" Kb	Kb	Eff. diam.
$0.8r_1$	82° 15'	0.0087"	0.0001"	0.376"	0.0294"	0.0006"	1.000"
$0.6r_1$	73° 47'	0.0072	0.0008	0.375	0.0244	0.0027	0.998
$0.4r_1$	63° 26'	0.0056	0.0022	0.374	0.0187	0.0072	0.993
$0.3r_1$	56° 50'	0.0046	0.0033	0.373	0.0154	0.0111	0.989
$0.2r_1$	48° 21'	0.0034	0.0051	0.371	0.0114	0.0174	0.983
$0.1r_1$	36° 0'	0.0019	0.0083	0.368	0.0065	0.0280	0.972

TABLE IV. HEIGHTS OF CONTACTS, ANGLES OF TANGENTS, CORRECTIONS FOR I.S.A. NOZZLES WITH $\beta < 0.67$.

Position	Height of contact	θ	Small Plug, r = 0.010" Kb	Eff. diam.	Large Plug, r = 0.034" Kb	Eff. diam.
0.8	0.24326 D_2	73° 29'	0.0082"	0.375"	0.0278"	0.999"
0.6	0.18245 D_2	68° 36'	0.0064	0.374	0.0216	0.996
0.4	0.12163 D_2	56° 19'	0.0044	0.373	0.0154	0.989
0.3	0.09122 D_2	50° 19'	0.0036	0.371	0.0122	0.985
0.2	0.06082 D_2	43° 7'	0.0027	0.369	0.0092	0.979
0.1	0.03041 D_2	32° 1'	0.0016	0.365	0.0052	0.968

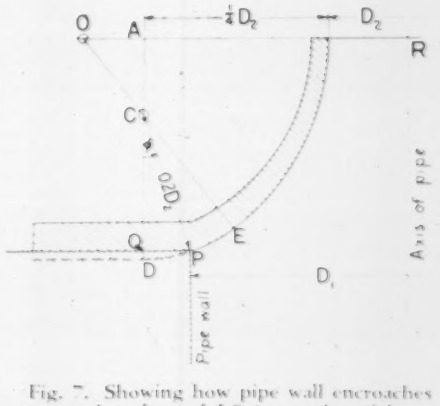


Fig. 7. Showing how pipe wall encroaches on curved surface of I.S.A. nozzles of large diameter ratio.

theoretical diameters at these positions may be calculated.

Referring again to Fig. 3 and equation (5) we have

$$y = r_2 / r_1 \sqrt{(r_1^2 - x^2)} \quad . \quad . \quad . \quad (5)$$

Let h = height of point of contact above surface plate MM'.

$$h + x = r_1$$

$$\text{or} \quad x = r_1 - h \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Substituting (15) in (5) gives, on expanding,

$$y = r_2 / r_1 \sqrt{(r_1^2 - r_1^2 + 2r_1 h - h^2)}$$

$$y = r_2 / r_1 \sqrt{(2r_1 h - h^2)} \quad . \quad . \quad (16)$$

As before, we want to know the diameters at selected fractional heights. Therefore let

$h = nr_1$ where n = 0.1, 0.2, 0.3, 0.4, 0.6, 0.8, successively.

$$y = r_2 / r_1 \sqrt{(2r_1^2 n - n^2 r_1^2)}$$

$$= r_2 / r_1 \sqrt{[r_1^2 (2n - n^2)]}$$

$$y = r_2 \sqrt{(2n - n^2)} \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

For simplicity of notation we may let $N = \sqrt{2n - n^2}$

$$y = r_2 N \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Applying this equation to the low β series of nozzles, defined by the equations

$$r_1 = D_2$$

$$r_2 = 2/3 D_2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

it is evident from Fig. 8 that the diameter D of the nozzle at a height h above the surface plate is given by

$$D = D_2 + 2r_2 - 2y$$

But since from (18) and (7) both y and D_2 may be expressed in terms of r_2 we have

$$D = 3/2 r_2 + 2r_2 - 2r_2 N$$

$$D = r_2 (7 - 4N)/2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

Table V gives the values of the multiplier for the selected measuring positions.

Not as much simplification is possible in applying equation (18) to the high-β ratio nozzles, which depend on both pipe diameter and throat diameter according to the equations

$$r_1 = 1/2 D_1$$

$$r_2 = 1/2 (D_1 - D_2) \quad . \quad . \quad . \quad (20)$$

In these nozzles the semi-major axes of the ellipses coincide with the pipe wall. Hence in Fig. 8

$$D_2 + 2r_2 = D_1$$

and it follows that

$$D = D_1 - 2y$$

$$= D_1 - 2r_2 N \quad . \quad . \quad . \quad . \quad (21)$$

(B) *I.S.A. Nozzle diameters.*

In Fig. 5, let the distance GK, taken at any desired height above the surface plate, be denoted by Z. Then for all points above the point E where the radius

TABLE V. VALUES OF N, $(7 - 4N)/2$ AND THEIR LOGARITHMS.

n	N	log N	$(7-4N)/2$	log $(7-4N)/2$
0.8	0.979796	9.99114–10	1.5304	0.18476
0.6	0.91652	9.96214–10	1.6670	0.22191
0.4	0.80000	9.90309–10	1.8000	0.25527
0.3	0.71414	9.85378–10	2.0717	0.31631
0.2	0.60000	9.77815–10	2.3000	0.36173
0.1	0.43589	9.63938–10	2.6282	0.41960

TABLE VI. VALUES OF MULTIPLIERS FOR COMPUTING DIAMETERS OF I.S.A. NOZZLES.

Position	θ	$1 - \frac{2}{3}(1 - \sin\theta)$	Log $[1 - \frac{2}{3}(1 - \sin\theta)]$
0.8	79° 29'	1.0412	0.001851
0.6	68° 36'	1.0451	0.018916
0.4	56° 19'	1.1087	0.044851
0.3	50° 19'	1.1536	0.062066
0.2	43° 8'	1.2109	0.083210
		$3 - 0.4 \sin\theta$	Log $[3 - 0.4 \sin\theta]$
0.1	32° 3'	1.2879	0.109859

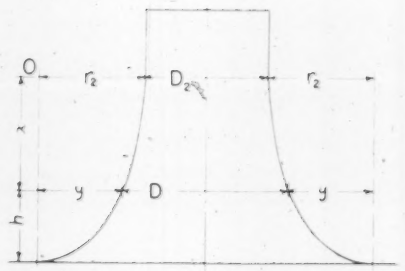


Fig. 8. Relations used in computing diameters of high-β ratio long-radius nozzles.

changes as previously explained, the diameter of the nozzle will be

$$D = D_2 + 2Z$$

But since GK = IB

$$D = D_2 + 2 (1 \ 3 D_2 - 1/3 D_2 \sin\theta)$$

$$= D_2 + 2/3 D_2 (1 - \sin\theta)$$

therefore $$D = D_2 [1 + 2/3 (1 - \sin\theta)] \quad . \quad . \quad (22)$$

For the first position, below the point E, it will be seen from Fig. 6 that

$$D = D_2 + 2(AB) - 2(MN)$$

$$= D_2 + 2(1/4 D_2) - 2(0.2 D_2 \sin\theta)$$

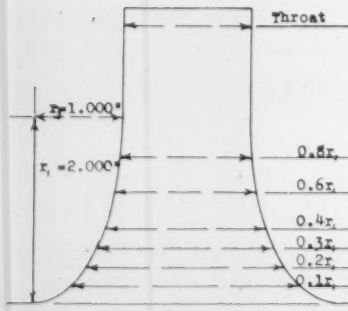
$$= D_2 (1 + 1/2 - 0.4 \sin\theta)$$

therefore $$D = D_2 (3 \ 2 - 0.4 \sin\theta) \quad . \quad . \quad . \quad (23)$$

In using Table VI, it must be remembered that, with nozzles of β greater than 0.67, the lowest position may be cut off by the pipe wall. In that event the nozzle diameter for that position, as computed above, is found to be greater than the pipe diameter, which is absurd.

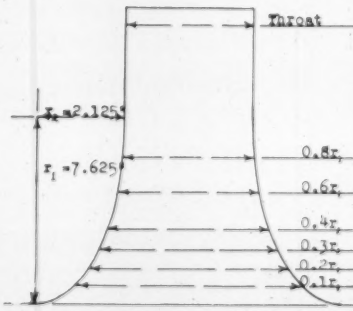
Figs. 9 and 10, with their tables, give the results of measurements on two nozzles of widely different size.

Fig. 9



	Diameters		Difference
	Nominal	Observed	
Throat	2.000"	1.9994"	
0.8r2	2.040	2.039	+0.001"
0.6r2	2.167	2.168	+0.001
0.4r2	2.400	2.403	+0.003
0.3r2	2.572	2.570	+0.002
0.2r2	2.800	2.799	+0.001
0.1r2	3.128	3.125	+0.003

Fig. 10



	Diameters		Difference
	Nominal	Observed	
Throat	13.00"	13.002"	
0.8r2	13.086	13.027	-0.059"
0.6r2	13.355	13.295	-0.060
0.4r2	13.850	13.833	-0.017
0.3r2	14.215	14.204	-0.011
0.2r2	14.700	14.707	+0.007
0.1r2	15.397	15.432	+0.035

Wear Resistance in relation to Hardness

Sixth instalment of "Hardness and Hardness Measurements." See page 3, Jan. 1937 issue.

By S. R. WILLIAMS
Professor of Physics, Amherst College

Saito[1] offers the following explanation of the mechanism of abrasion:

"The surface of any material, even if it may appear to the naked eye to be smooth, has innumerable microscopic protuberances which look like the teeth of a gear wheel. Now, if the surfaces of any two materials come into repeated contact during rolling or sliding under a certain pressure, the protuberances on these surfaces of contact break down by fatigue, giving rise to new protuberances. The abrasion is caused in this way and the amount of the protuberances broken down is the amount of wear. The worn off powder present on the contact surface of two test pieces plays the same role as the proturberances, or as saw-teeth, thus resulting in a greater amount of wear. If the powder is harder, it acts like the hard teeth of a saw and results in a greater abrasion than in the case where it is not so hard."

"Now let us consider the abrasion experiment between the same material. In the combination of the test pieces of the same material rotating at the same speed, the number of proturberances coming into contact in each test piece, and consequently the dipping in it will no

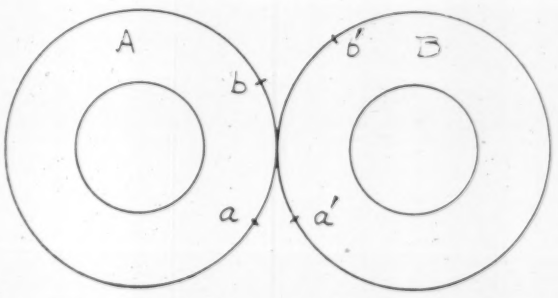


Fig. 34. Theory of difference of rate of wear.

doubt be the same with each other. But if the speed of A is smaller than that of B, there is a slipping $a'b'—ab$, as is shown in Fig. 34, the contact lengths of A and B being ab and $a'b'$ respectively in the same duration of rotating. In other words, the contact area of A covered in a given period is smaller than that of B. Thus, if the protuberances in a unit area of these contact surfaces is the same or nearly the same, a smaller number of the protuberances of A will come into contact with a larger number of them in B. By virtue of this difference in the number of contacts the destruction of protuberances on A is greater in number than that of the protuberances on B."

Saito proceeds then to show that his results are in agreement with his proposed theory. One striking agreement is in the increased abrasion of the slow moving disk as the slippage is increased. The results, it would seem, might have been deduced from the experience of those who use diamond saws in cutting glass. In this process, a thin sheet of soft metal is cut in the form of a circular disk. By tapping the edge of this disk into a small pile of powdered diamond, small particles of the latter will imbed themselves in the edge of the soft metal disk and form a saw which may be used in cutting hard materials. The particles of diamond carry away the particles of the material to be cut. It is an abrasive process concentrated along a narrow line. As will be seen later, it is a continuous scratch process in which there are many points following one after the other in the scratch made by its predecessor. Increasing the speed, (i.e. the slippage) increases the rate of cutting (abrasion) as Saito found in his work. Furthermore, it does not seem necessary to invoke the property of fatigue to have Saito's protuberances broken off. They are simply broken off by reason of weakening due to undercutting and other abrasive processes. The powder formed by abrasion performs the part carried out by the diamond pointer on the cutting saw just described. These particles, since they will be predominantly harder than the mass from which they are cut, will imbed themselves in the disks as did the diamond powder, and so the cutting (abrasion) goes merrily on. The value of speed in cutting may be seen in spinning a circular disk of writing paper at high angular speed and using it as a buzz saw for cutting substances much harder.

Saito suggests that his work may be applied to the design of bearings. He says, "If two contact surfaces consist of different materials, the harder one must be used on the side which has the larger contact area per unit of time." This is exactly the practice wherever one meets with a steel shaft rotating in a Babbitt metal bearing.

RUBBER ABRASIVE RESISTANCE TESTER

The American Instrument Co. has developed an outfit, designed to simulate the wear and tear on rubber materials over a long period of time. A drum 6" in diameter is driven by a $\frac{1}{4}$ h.p. motor at a speed of about 45 r.p.m. On the surface of the drum is fixed a continuous sheet of standard garnet paper. This serves as the abrasive and is held on the drum by rubber bands.

The test specimens of rubber are 1" square and $\frac{1}{4}$" thick. Three of these can be tested simultaneously. They are held under levers which may be weighted as shown in Fig. 35. By means of a Veeder counter the distance of travel of the specimens of rubber over the abrasive

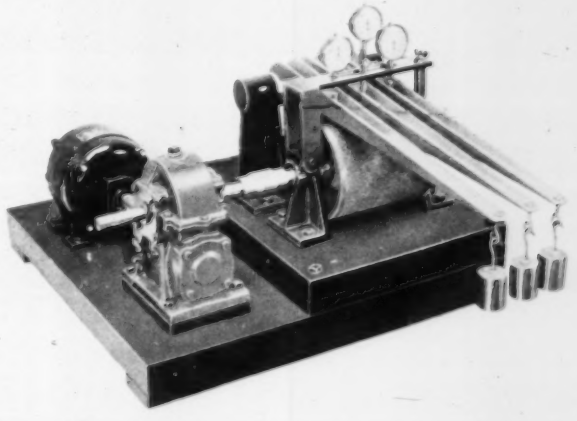


Fig. 35. The American Instrument Co.'s abrasion test machine for rubber products.

[1] S. Saito, A Study of Abrasion, *Science Reports of the Tohoku Imperial University Series I*, Vol. 20, 1931, pages 560-573.

surface may be obtained. The amount of wear is determined by dial gages readable to 0.001". In practice, the weights on the three levers are adjusted to give a pressure of exactly 5 lbs.

WEAR TESTS ON HARD ALLOYS

In comparatively recent years there have been developed hard alloys which are being used in cylinder liners for engines and pumps, as well as in many other applications. The fact that these alloys showed high hardness numbers by some of the standard methods did not necessarily give assurance that they had high wearing power. In a recent paper, Freeman[1] studied relative wear resistance of some of these hard alloys by a test in which wear was accomplished by pure sliding contact. Distillate was used in these tests because of its low lubricating properties. The attempt was made to simulate actual working conditions.

Haynes Stellite, a chromium-aluminum-molybdenum steel, a nitrided nitralloy, a case-hardened steel, white cast iron, and an alloy cast iron were some of the materials tested. If the alloy of cast iron on an alloy of cast iron had a wear ratio of 100 then these various alloys ranged all the way down to Haynes Stellite on Haynes Stellite with a wear ratio of 0.4.

In summary, the author states, "Tests and apparatus have been described by which the relative sliding wear resistance of some hard alloys has been determined. The surface conditions accompanying wear have been shown with photomicrographs of the worn edges. Both smooth and ridged surfaces were accompanied by a structure which was indistorted and smooth even under the microscope. The galled surfaces were accompanied by a worked layer of hard material, which, in the case of white cast iron, was shown to consist of iron carbide with small grains of pearlite interspersed throughout."

[1] R. B. Freeman, The Relative Wear of Some Hard Metals, *Metal Progress*, Vol. 31, 1937, pages 281-284.

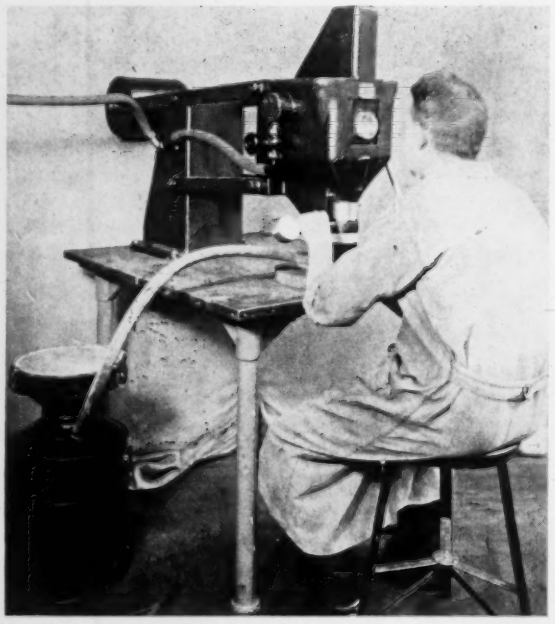


Fig. 36. Zeiss abrasive wheel hardness tester in practical use.

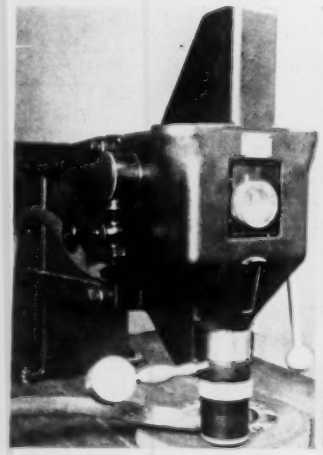


Fig. 37a. Compressed air connections for blowing sand.

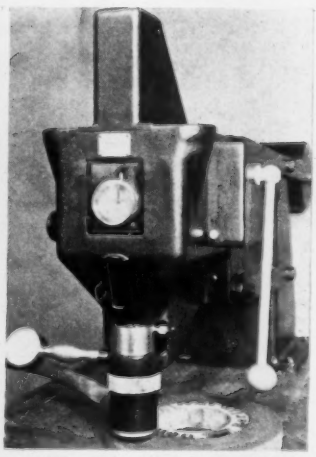


Fig. 37b. Operating levers on Zeiss instrument.

ABRASIVE WHEEL HARDNESS TESTERS

Before leaving the topic of abrasive methods for measuring hardness two other methods should be mentioned. First, the Zeiss Abrasive Wheel Hardness Tester. This is a device whereby a jet of sand is blown at a definite point on the surface of the specimen to be tested and the resulting hole then has its depth measured when a definite quantity of sand has been directed at this one point. It finds a wide use in testing the hardness of grinding wheels and could be employed to advantage in the measurement of different kinds of glasses, marbles or granites.

Fig. 36 shows the instrument in practical use. Figs. 37a and 38b show the operating levers and the connections for the compressed air and the sand. Fig. 38 shows the essential elements of the hardness tester with the abrasive or grinding wheel *a* in place ready for testing. The left hand grasps the handle *b*, moving the instrument body on a parallelogram *c* so as to bring the mouth piece *d* in contact with the work *a*. With the right hand the dial gage *e* is set at zero. Lever *f* is then pulled forward to its limit, thereby opening the compressed-air cock and allowing a measured amount of sand to pass through the nozzle.

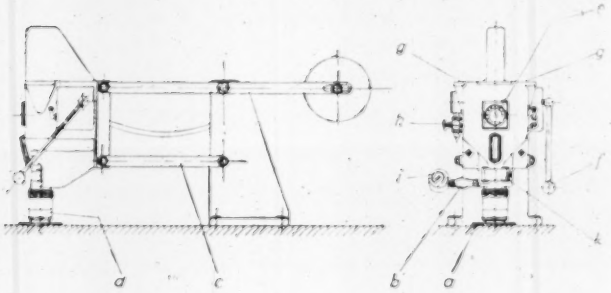


Fig. 38. Details of Zeiss abrasive wheel hardness tester.

After the sand has all been blown through, as evidenced by the change in noise, lever *f* is pushed back to its rear limit, and the depth of the hole produced by the sand blast is read from the gage *e*. It is desirable that the sand should be of a standard gage about $\frac{1}{20}$ of an inch in diameter for the grain size. The sand is filled into the storage hopper at *g*. Stopcock *h* is used in adjusting the compressed air, the pressure of which is read from the manometer *i*. At the discretion of the operator, the pressure may be set at 7 or 42 pounds per square inch above what is called a normal pressure, or at this normal pressure different quantities of sand may be used, varying between 0.3 and 6.3 cubic inches of the same.

It is only fair to add that, after all, the Zeiss instrument really tells us more about the bonding material than it does about the grains of the abrasive held together by the bond. When the sand blast is shot against the grinding wheel, only the bonding material is cut

(Continued on page 163)

Cathode-ray Oscillograph Applications

A fourth part of "The Cathode-ray Oscillograph and Its Applications", being published serially in *Instruments*. This series began in July 1936 issue.

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

REGULATION OF WATCHES[10]

Vibration pick-ups employing piezoelectric crystal elements have been used for several years in chronographs for the regulation of watches and clocks. One manufacturer asked for a pick-up to be used with a small wrist watch measuring only 1" × 3/8". The tick of these watches is hardly audible. Before a pick-up of the high sensitivity required could be made it was necessary to know what frequencies predominated. One of these small watches was mounted on a Brush "VP-1" vibration pick-up. The output of the pick-up was fed through a vacuum-tube amplifier into a cathode-ray oscillograph. Using a beat-frequency oscillator it was found that the watch tick produced a range of frequencies from 60 to 17,000 c.p.s. The dominant frequency was found to be 3,000, with less prominent frequencies at 7,000 and 17,000.

The crystal element used is designed to have a natural period of 3,000 c.p.s. as it will generate a maximum voltage for a given amplitude of vibration when excited at its resonant frequency. The unit employs the inertia principle, the vibratory forces being transmitted through a driving pin to the element supports. The bender element is mounted at its mid-point to a small aluminum frame equipped with a driving pin at one end and pivited at the other.

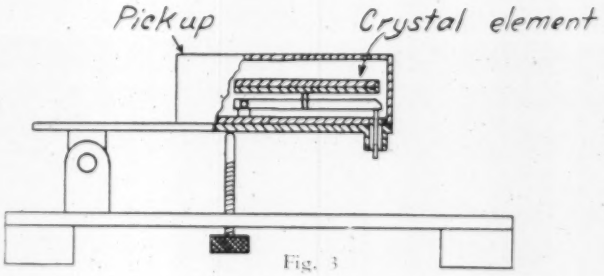


Fig. 3

It was found that the watch produces the greatest amplitude of vibration when placed on its edge so that the escapement wheel will be operating in a vertical plane. The point of greatest vibration was found to be on the top edge close to the escapement wheel.

In operation the pick-up is arranged as shown in Fig. 3. The driving pin of the pick-up makes contact close to the escapement wheel. Vibrations caused by the movement of the escapement system cause the crystal element to generate voltages similar in characteristics to the vibrations. These voltages are amplified by means of vacuum-tube amplifiers. They may then be converted back into mechanical impulses which are compared with standard impulses produced by synchronous machinery.

ELECTRON MICROSCOPES AND TELESCOPES

Among special-purpose applications of cathode rays, that of the electronic microscope has received a great deal of attention. The principle of electron optics is already widely utilized in practice in the concentration of the electron stream. However it is as easily possible to produce the effect of a diverging lens by altering the electrode design so as to interchange the position of the focal points in the system; thus spreading the image of the cathode to cover the whole screen. When such an image is correctly focused, it is found that the emission variations of the various points on the surface appear greatly enlarged.

A practical adaptation of this principle has been disclosed by Zworykin in his electron telescope. His tube differs from the usual tube of the type described in the preceding paragraph, in that the cathode is of the caesium-caesium oxide-silver photoelectric surface. In the usual case a particular view is projected thereon, such as the magnified image of some microscopic organism placed on the stage of the ordinary microscope and illuminated by some external source. Thereupon the electronic emission from this cathode is further magnified electronically and reproduced on the fluorescent screen. Beside the possibility of thus securing further magnification, this tube enables the demonstrating of the specimen to large groups, and enables the image to be viewed with a minimum of eye strain. It also is possible to view the object illuminated with ultra-violet (or infra-red) light if the photoelectric surface provided is sensitive to such wavelengths. At the other extreme, the image received through telescopes can likewise be focused on the cathode for subsequent reproduction on the fluorescent screen.

[10] *Brush Strokes*, Vol. 3, Nov. 1936, Brush Development Co., Cleveland, Ohio.

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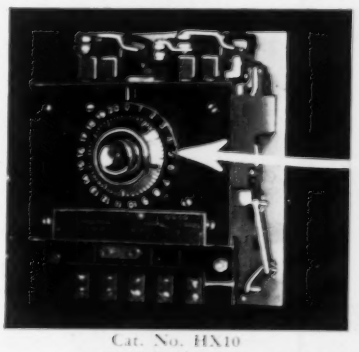

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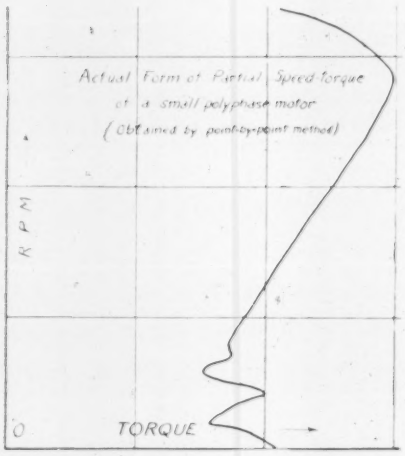
APRIL PROBLEM (No. 6)
SPEED-TORQUE AUTOGRAPHS

"We manufacture a large variety of fractional- and integral-horsepower motors, and have to have speed-torque curves on each new design. It is difficult to obtain the 'unstable' portion of the speed-torque curve on a dynamometer, by reason of heating of the motor rotor. Moreover, the familiar methods employing recording instruments require calculations from two or more simultaneous records: speed and torque; time and known inertia of disk; etc. What we require is a method whereby each curve will be drawn directly on a rectangular chart, of which the coordinates are speed and torque."



Here's what made Problem No. 6 tough.

Seven solutions of Problem Number Six were submitted. All evinced careful preparation, and your editor's first thought was to accept them all for publication in this month's Forum. Our second thought was to try a new procedure: instead of our being judge and jury as we had been in connection with the first five problems, why not send all manuscripts and drawings by registered mail to the Test Engineer whose urgent inquiry a few weeks ago we printed as Problem Number Six? Why not let him be the judge, or the jury, or at least the "expert witness"?

That is what we did, and the outcome shows that, in such cases, second thoughts are best. The Test Engineer pointed out something that makes this month's Forum much more interesting, namely the nature of the chief difficulty. This had been stated plainly enough ("It is difficult to obtain the 'unstable' portion . . . by reason of heating of the motor rotor") but most of the seven suggestions did not evince full appreciation of all that the words "unstable" and "heating" implied.

In the first paragraph of his letter returning the manuscripts to us, the Test Engineer put the whole thing in a nutshell: To obtain the unstable portion "quickly enough to wash out the effects of rotor heating," he stated, "the whole curve must be drawn in 30 to 60 seconds."

Less than a minute! Consideration of inertia effects compelled the rejection of suggestions we had admired for their ingenuity, clear exposition and good draftsmanship. One of these was based on the use of an eddy-current brake, but under the required conditions even a relatively light aluminum disk would introduce inertial errors far greater than allowable.

Two others involved modified cradle dynamometers. (By the way, the Test Engineer is not unfamiliar with these electrical dynos, as he uses seven of them, ranging from a small eddy-current device to a 100-hp. generator type.)

Two suggestions involved Prony brakes. Neither was accepted by the Test Engineer but we nevertheless publish one (Hawley's) because it could be used in some cases where starting torque is maximum torque.

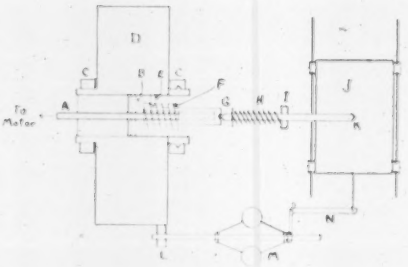
A distinguished physicist suggested the use of a propeller whose pitch could be changed to vary the torque, but the Test Engineer declares that this idea neglects starting torque, inertia effect of propeller and calibration. ("The propeller would have to be calibrated at a great number of speeds and a great number of pitches; and the set-up would not draw a speed-torque curve—it would draw a speed-displacement curve and then, from a calibration chart, a speed-torque curve could be drawn.")

Only one was marked "Possible" by the Testing Engineer: Elmo Hanson's.

Now as to the future: your editor hasn't decided whether he will again show a monthly batch of suggestions to anyone else before publication. He can only promise that he'll keep up the interest-value of this Forum, adapting the means to the needs—calling on "expert witnesses" when, as and if . . . —MFB.

$5 PRIZE SOLUTION
By ELMO E. HANSON
MINNEAPOLIS, MINN.

Shaft A transmits power from the motor to flywheel D entirely through spiral spring B. The flywheel is of such an inertia that an appreciable interval (say ½ minute) will elapse from the time the motor is started until it is up to top



speed. Bearings C support the flywheel with a minimum of side-play. Now the angular displacement of shaft A with respect to the normal zero torque position of D is directly proportional to the torque acting through A. Shaft A is keyed to a worm gear F in such a way that while it must rotate with the shaft, it is free to slide along its length. A pronged member E fastened to the inner side of the hub of the shaft through D engages this worm gear. Therefore any angular displacement of shaft A with respect to D is translated into a lateral motion of F. This motion is transmitted through the pivot bearing B to the recording pen K. The pen arm rests in guide bearing I and is held against the pivot bearing by a weak spring H. A carriage J holding the recording paper rolls on tracks which are perpendicular to the pen-arm. The positions of the carriage on the tracks is controlled by the speed of the motor: L is a friction pulley or gear meshing with the flywheel, M is a governor arrangement for actuating the lever N and therefore J. Obviously in practice this simple mechanical arrangement would have to be modified to give a linear relationship between the position of J and the speed of the motor.

The instrument could be calibrated in torque by applying known static torques to the shaft A and noting the corresponding positions of the recording pen. The calibration in speed would necessitate the rotation of D at constant speeds (use synchronous motor plus speed controller) and the recording of the corresponding trackwise positions of the pen.

$5 PRIZE DISCUSSION
By PAUL F. HAWLEY
LOS ANGELES, CALIF.

This problem could be restated as: (a) required to produce measuring apparatus recording linearly speeds up to 3600 r.p.m., and torques of the order of 6 to 10 pound-feet maximum, and (b) required to arrange the recording system so that the speed-torque curve is drawn directly. The following is a somewhat elaborate method of accomplishing the desired result. Directly measured are: (1) voltage produced by a miniature alternator of constant field, directly coupled to the shaft of the test machine, and (2) pressure exerted by the arm of a Prony brake.

One possible form of apparatus applicable to small motors is shown in Fig. 1. Here both Prony brake and alternator are shown combined in one hand-operated piece of equipment. This consists of two parts: the brake and stator of the alternator, and the rotor of the alternator.

The brake is made with a hole to fit the shaft (or shaft adaptor) loosely, and is split so that by squeezing the handles the brake is tightened. The end of the lever is bent at right angles and is attached to one end of a variable-resistance carbon pile. The base of the pile is rested against a solid support by the test motor base, so that the pressure applied to the pile will be directly proportional to the torque applied by the motor to the brake. Within a limited range, the resistance of such a pile varies inversely with the pressure applied, so that by use of a suitable pile, there will be a constant ratio between pile conductivity and motor torque. By using the quite common series resistor-battery circuit shown in Fig. 1, the voltage across R will vary directly with the motor torque. For example, a 1000-ohm carbon pile can be made to have a 10% resistance change with a force of 100 lbs. If the lever arm of the brake is 0.1 ft., this force is produced by a torque of 10 ft.-lbs. If R is

4000 ohms and E is 90 volts, the ... in voltage drop across R is a ... over 2 volts.

The speed indicator is made up of the ..., attached to the brake, and the ... The rotor is shown by itself in ... 2, and consists of a permanent mag... attached to a coupling with tapered ..., so that it can be driven on the ... shaft by hand. The stator is a ... iron ring wound with two sets ... coils, as shown. When the brake has ... put on the shaft, the rotor is forced ... place, and the brake is held against ... rotor collar. This aligns the rotor ... stator. As the air gap is constant, the ... magnet flux is constant, and the voltage generated in the stator coils is directly proportional to the speed of the shaft.

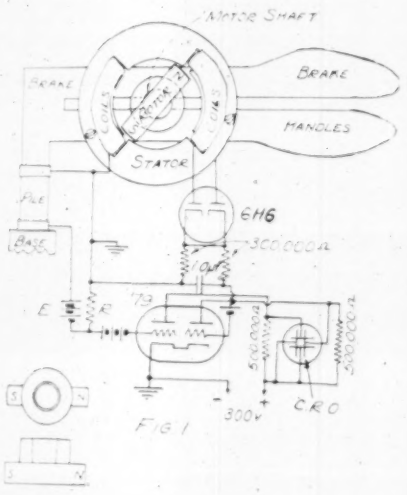


FIG 1

FIG 2

A simple calculation will show that it is easy to generate an output voltage of around 2 volts at 1800 r.p.m. with the arrangement shown.

Having produced voltages directly proportional to torque and speed, it still remains to record these simultaneously on mutually-perpendicular axes. The most obvious recording instrument satisfying these requirements is the low-voltage cathode-ray oscillograph. However, the generated voltages are too low to give readable deflections of the beam, and the amplifiers ordinarily furnished for these oscillographs are resistance-coupled, so that the slow change in voltage produced in the speed-torque cycle would not be correctly recorded. However, a simple d-c. amplifier can easily be made which will give a voltage swing of around 90 volts with a two-volt grid swing. 90 volts is ample to give a good deflection on a low-voltage oscillograph. Such an amplifier is shown in Fig. 1. For simplicity, a twin triode '79 tube is used, one unit furnishing the horizontal deflection (speed) and the other the vertical deflection (torque). However, the type of amplifier is relatively unimportant, the requirements being that it be capable of amplifying direct currents, and produce around 100 volts swing (or whatever amount is considered to give ample deflection on the oscillograph).

The "speed" voltage is generated as variable frequency a.c., so must be rectified and filtered before applying to the d-c. amplifier. In Fig. 1 a double diode 6H6 rectifier tube and a filter circuit are shown, although a full-wave copper oxide rectifier and filter could be used.

When using the setup, after slipping the brake on, tapping the rotor in place, and aligning the two parts, the motor is thrown on line, and the load applied by squeezing the brake arms together. As the motor slows to a stall, the speed-torque curve will be drawn on the oscillograph screen. Permanent records can be obtained by photographing the oscillograph face. This part is too well known from Batcher's recent *Instruments* articles to require description, except to mention that the speed of the spot is very low, which facilitates photographic recording. The resultant picture can be enlarged as far as necessary for study.

Calibration of the arrangement is simple, and can be done for each curve, if desired. The torque calibration is secured by applying a weight at a known distance from the brake pivot, and noting or photographing the oscillograph deflection. Similarly, the test motor can be brought up to speed, checked with a tachometer, and the oscillograph deflection measured as before.

This apparatus is too elaborate to be justified in testing one or a few motors, but should be quite useful for rapid testing of many machines. I do not believe that over five minutes would be required for the entire operation.

Problem No. 8 Subject Index 2.07

THERMAL CONDUCTIVITY

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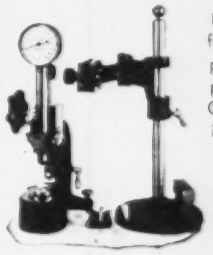

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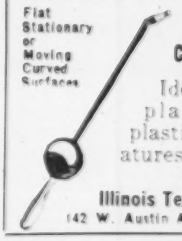

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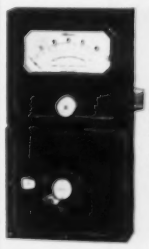

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WEAR RESISTANCE and HARDNESS

Continued from page 165

away, and the rate of cutting will depend upon at least two factors: the hardness of the bond, and the distribution of the grains of the abrasive in the bond. If the abrasive grains are close together, the grains of the sand blast can't get at the bond material to cut it away.

The Abrasive Engineering Corporation (Detroit, Michigan) have a device for sale under the trade name "Grade-o-meter," the claim for which is that it will measure the strength of the bonding material. This is important because the strength of the bond determines when the abrasive grains of the grinding wheel will be discharged from its surface. If the bond is too hard the abrasive grains remain until all of their cutting edges are removed and they act as burnishers rather than as abraders. On the other hand, if the bond is too soft the abrasive grain will be discharged from the wheel before proper wear has been obtained for cutting purposes. Fig. 39, showing how the abrasive grain and its bond are related, brings out the importance of such tests on the bond. Figs. 40a and 40b show a general view and a close-up of the machine which this Company produces. It is a device for mechanically measuring the strength of the bond by digging out depressions in the side of the grinding wheel. It suffers the same limitations as the Zeiss instrument in that it is a question as to just what physical property of the wheel as a heterogeneous aggregate is actually tested or measured. *To be continued*

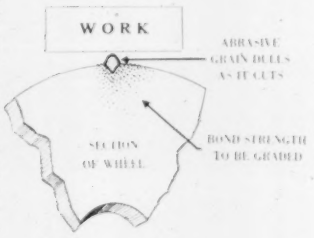

Fig. 39. This diagram explains not only the relation between the abrasive grain and its bond, but also how in all substances there may be local areas whose hardness is much greater than that of others. Also if one were using a piece of a grinding wheel with which to scratch a crystal to test its hardness, the results would depend on whether the abrasive grain or the bond was doing the scratching.

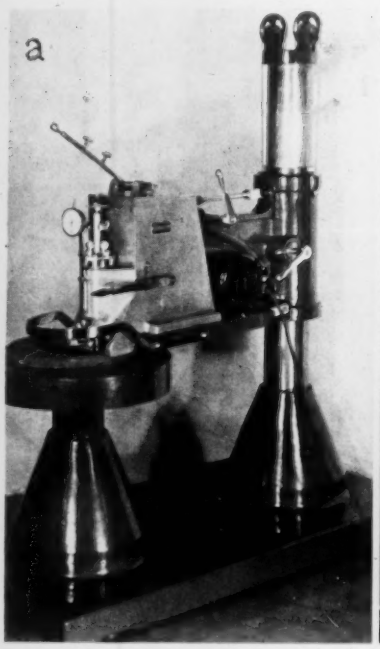

Fig. 40a

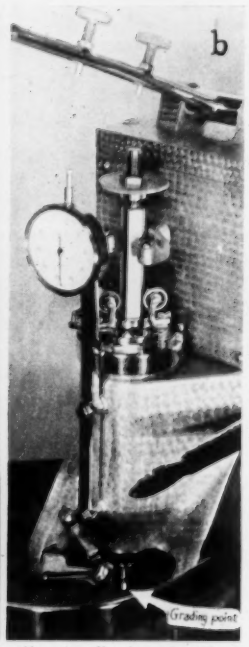

Fig. 40b

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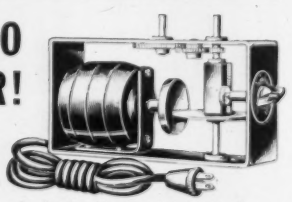

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STORAGE BATTERY LIFE TESTS

Continued from page 157

Since the value of the results from an automatic test such as this depends so largely upon the accuracy and dependability of the instruments used, care should be used in their selection. Panel instruments of at least 1% accuracy should be used, while for the test benches instruments should be calibrated to ¼ of 1% accuracy. The program machine should preferably be driven by a synchronous motor to decrease timing errors.

The schedules used in our test for starting batteries and for farmlight cells are as follows:

TABLE 1

	SLI Schedule	13 plate Farmlight
Discharge time	2 hours	3 hours
Discharge rate	25A. average	20A. average
Discharge A.H.	50 A.H.	60 "
Charge time	4 hours	3 hours
Charge rate	17.5A. average	26.7A. average
Charge A.H.	70 A.H.	80 A.H.
Breakdown cycles per week	27	24
Capacity cycles per week	1	1
Capacity cycles disch. rate	200A/80°F	15A/80°F
Battery fails at yield	4 minutes	4 hours

During the automatic breakdown cycles the batteries are in room temperature air, with battery temperatures usually between 110 F. and 130 F. They are cooled in water to 80 F ± 5° for the weekly capacity cycle. The life of a 13-plate farmlight cell on this test should be 500 cycles, based on present estimate that 100 cycles are equivalent to a year's normal use.

In evaluating SLI batteries the following table of ratings used is based on the many tests that have been run:

Relative Life of Group 1 Batteries

Battery Warrantee (Standard System)	Life rating in Cycles: Minimum	Fair	Good	Excellent
6 month	60	90	120	150
12 month	120	175	225	300
18 month	180	240	300	400
24 month	240	300	400	500

As we find that our test results are of the same order as those from the recently adopted S.A.E. life test, we are continuing to use our own method. The large mass of data we have built up using it also makes it desirable that we keep on as we are, even though the only changes required in the circuit to adjust to S.A.E. are new contact strips in the program machine and resetting of resistors.

The technique of testing storage batteries has not been an overnight development but is the result of long continued study and development and will no doubt continue to develop and change as future needs require.

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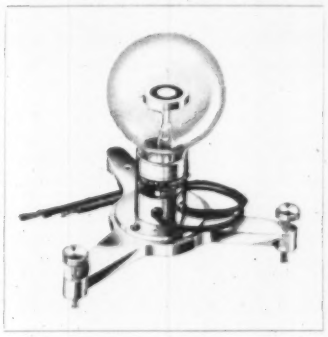

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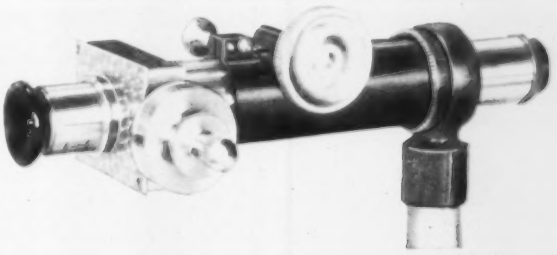

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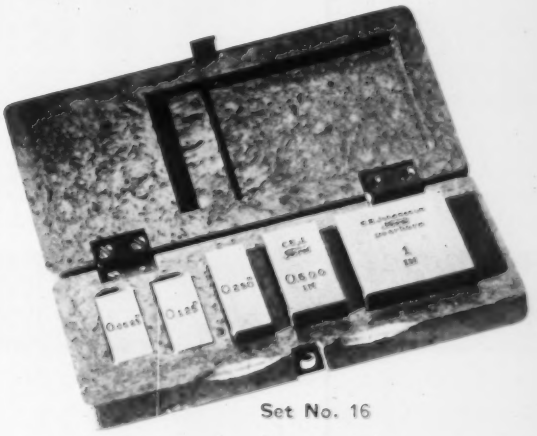

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